Lecture-1

CSE 359
Computer Networks

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Class code: a4iaui6
Class link: https://classroom.google.com/c/NzIyNjAxMDc4MzMy?cjc=a4iaui6
Meet link: https://meet.google.com/vts-wgoo-nfh

Books

Computer Networks (5th Edition)
Andrew S. Tanenbaum

Data Communications and Networking (6th Edition)
Behrouz A. Forouzan

Data And Computer Communications
William Stallings

Computer Networking A Top-Down Approach
James F. Kurose and Keith W. Ross

Computer Networks

- ✓ The old model of a **single computer** serving all of the organization's computational needs has been replaced by one in which a large number of **separate but interconnected** computers do the job.

- ✓ A **computer network** is a set of connected computers (called node) for the purpose of communicating data electronically or to share resources.

- ✓ Today's **Internet** is arguably the largest engineered system ever created by mankind, with hundreds of millions of connected computers, communication links, and switches; with billions of users.

- ✓ Users are connected via laptops, tablets, and smartphones; and with an array of new Internet-connected devices such as sensors, Web cams, game consoles etc.

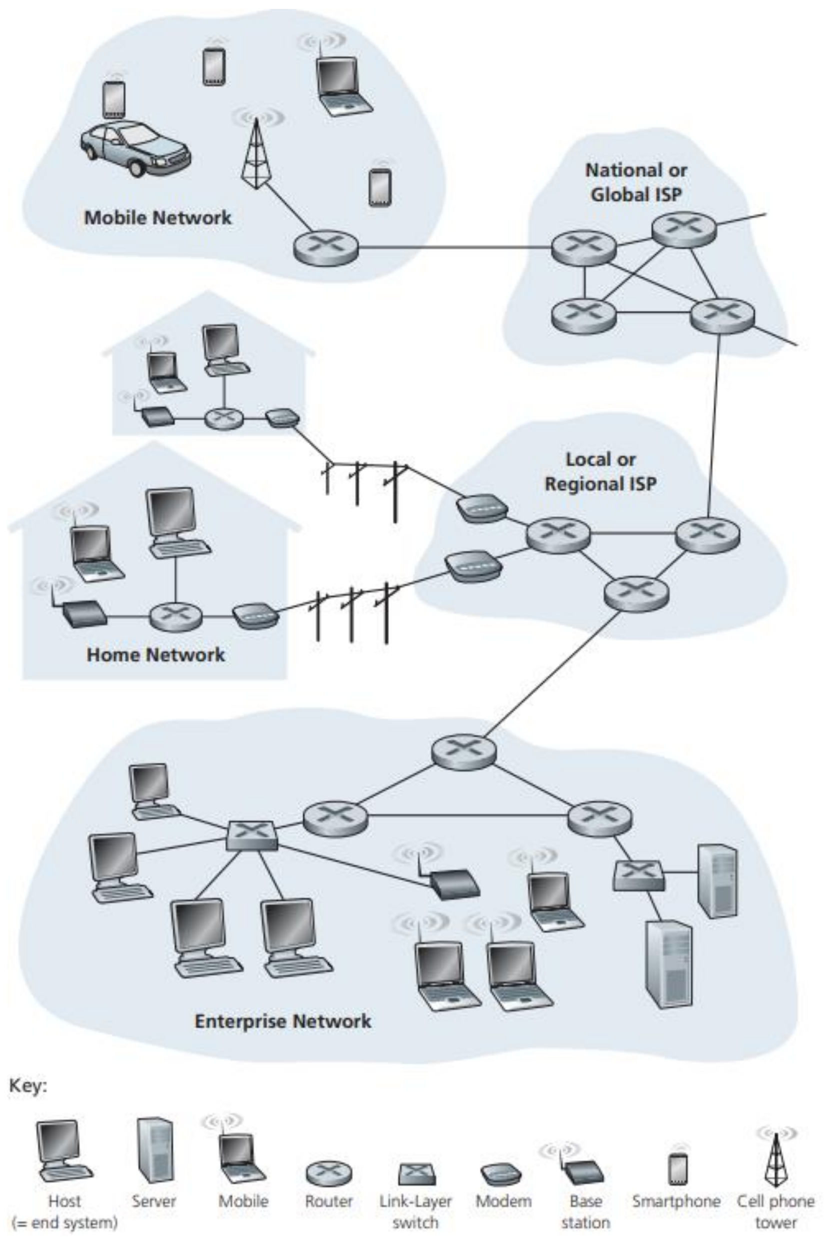
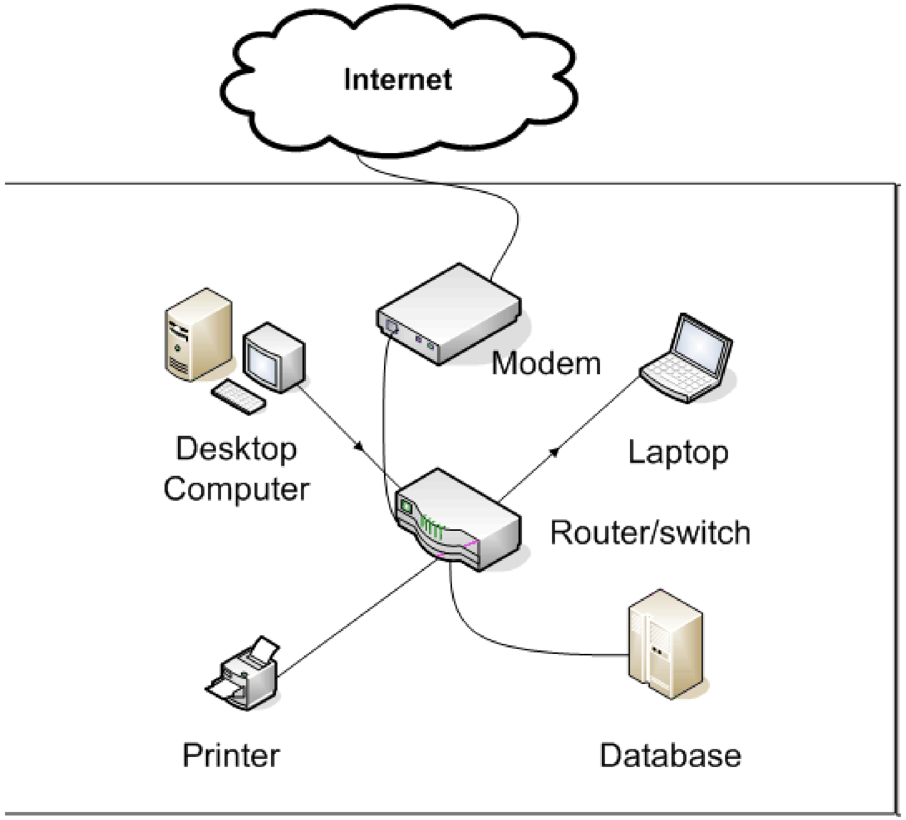


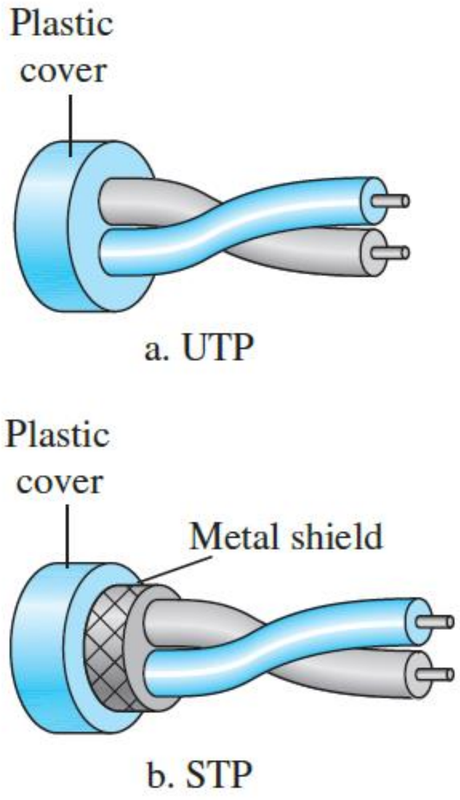
Fig.1 Some pieces of the Internet

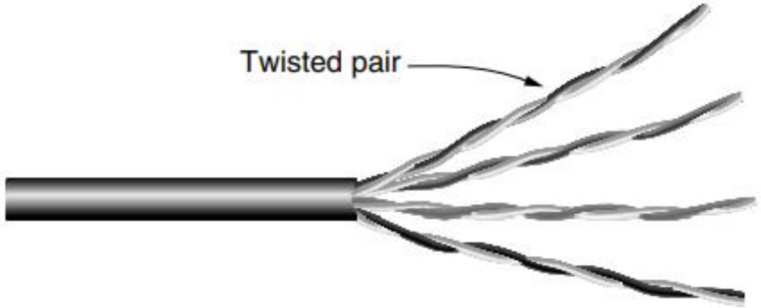
Components of Computer Network



PC (Basically is a personal computer), NIC (Network Interface Card), Hub, Switch, Router, Connectors, Modems, OLTE, and physical transmission medium (wired or wireless).

Physical Transmission Medium

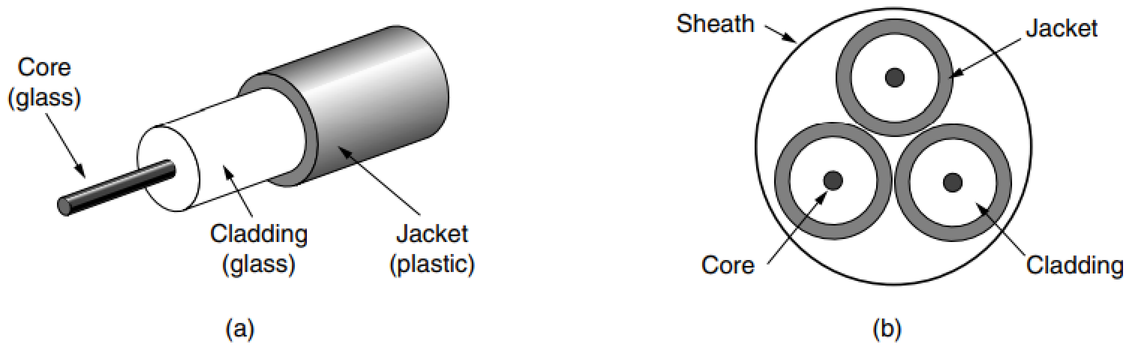




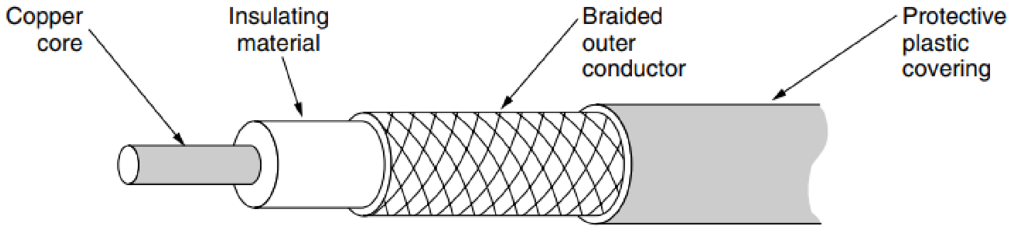
UTP (Cat 5, Cat 6, Cat 7 cables)

Unshielded twisted pair (UTP) and shielded twisted pair (STP)

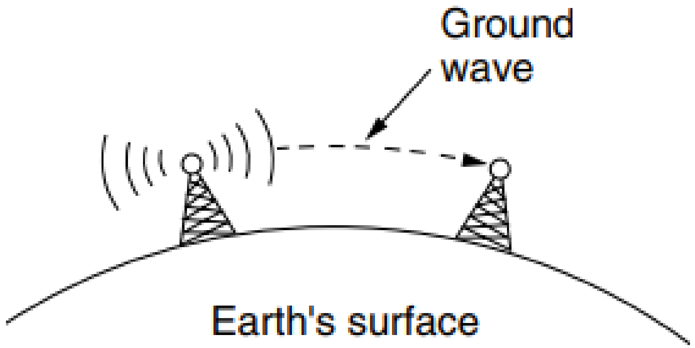
Physical Transmission Medium



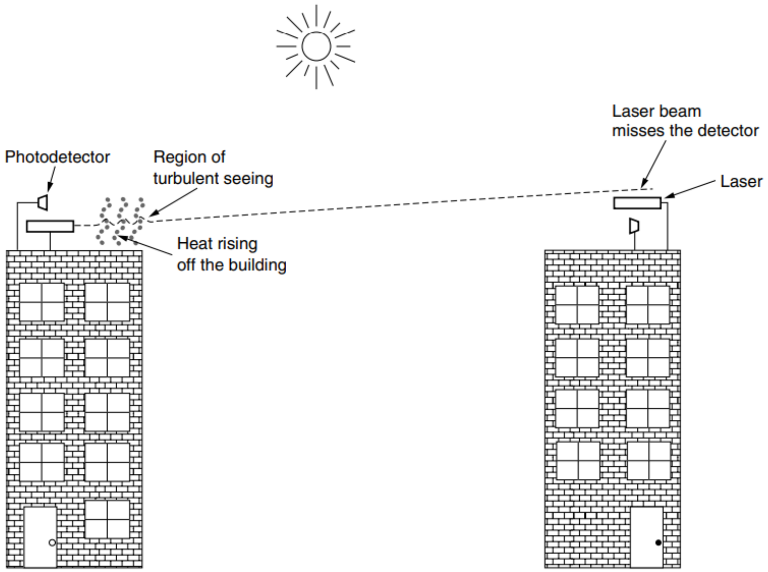
Optical fibre



Coaxial Cable



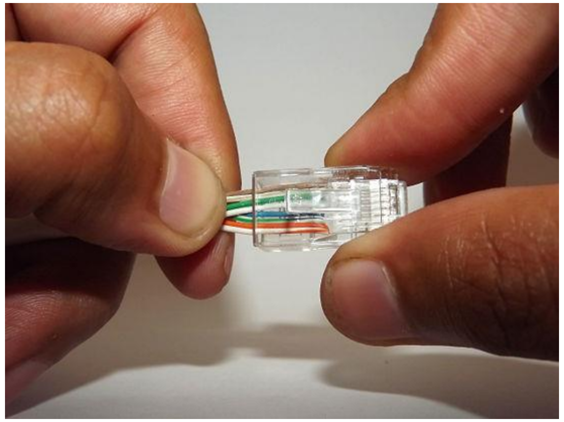
Wireless Communication



laser communication systems

BNC Connector

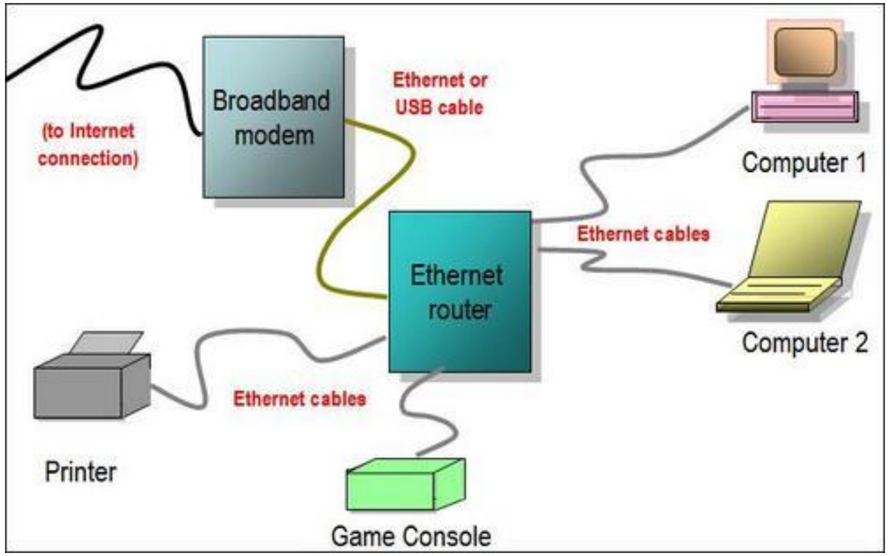
British Naval Connector or Bayonet Nut Connector



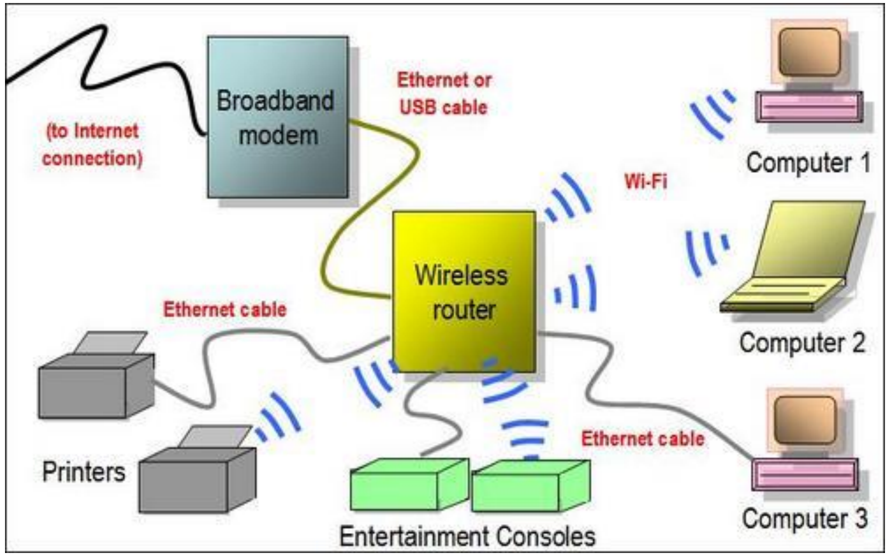
RJ45(Registered Jack) Connector

Modem

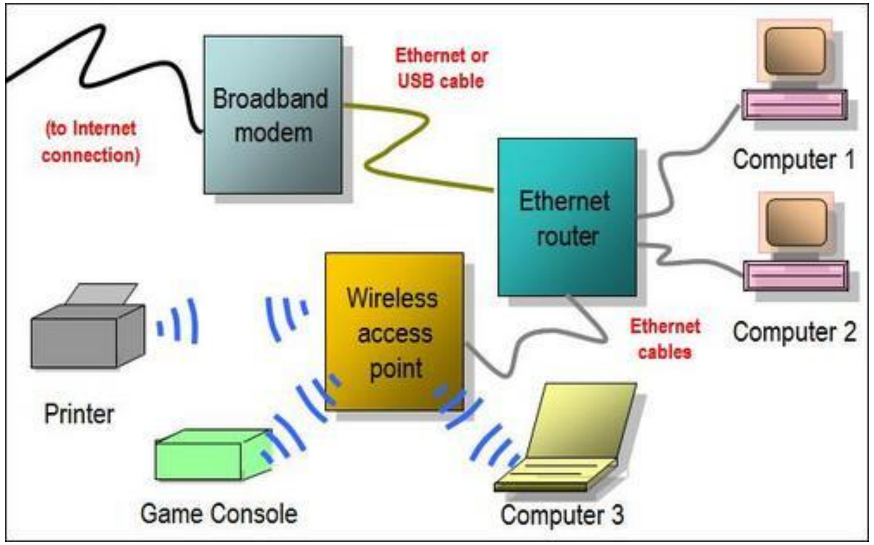
OLTE



Wired Network

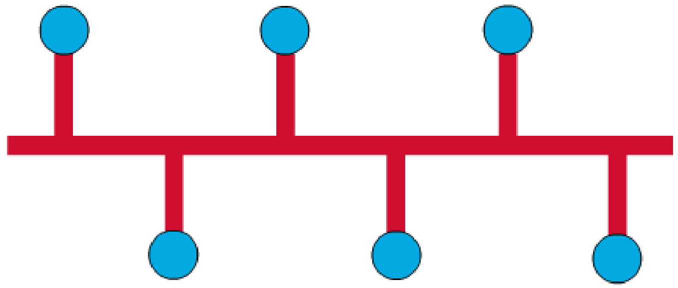


Wireless Network

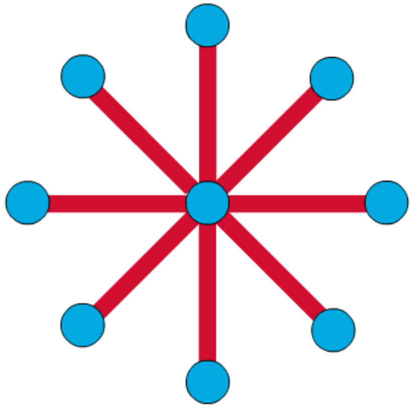


Hybrid Network

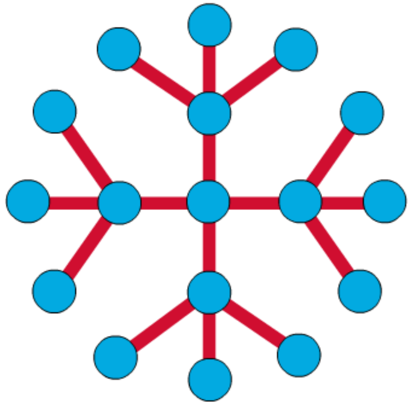
The **network topology** defines the way in which computers, printers, and other devices are connected.



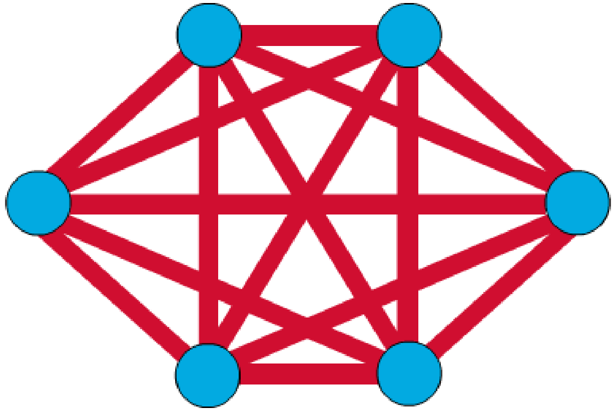
Commonly referred to as a linear bus, all the devices on a bus topology are connected by one single cable.



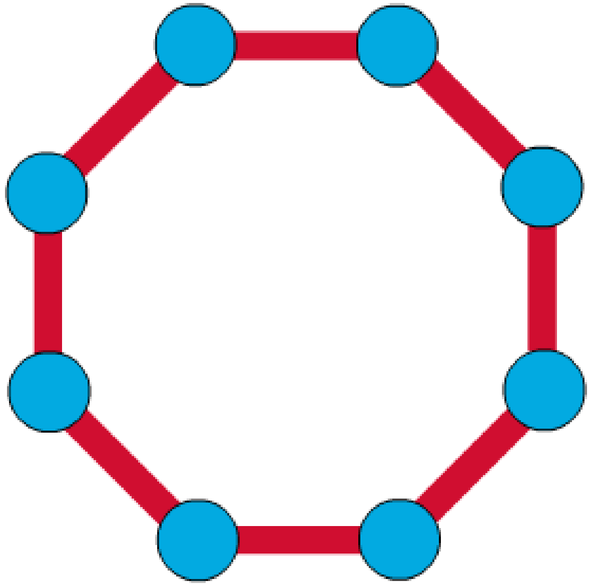
The star topology resembles spokes in a bicycle wheel



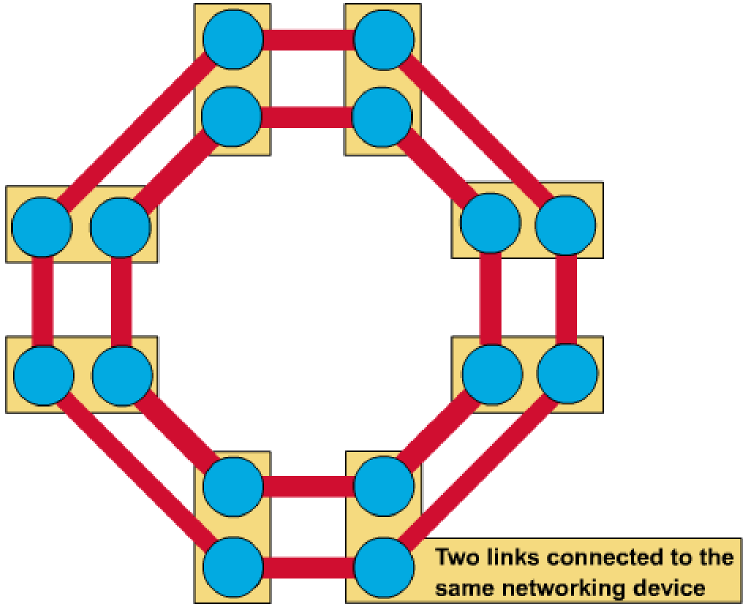
Larger networks use the extended star topology also called tree topology.



The mesh topology connects all devices (nodes) to each other



A frame travels around the ring, stopping at each node (ring topology).



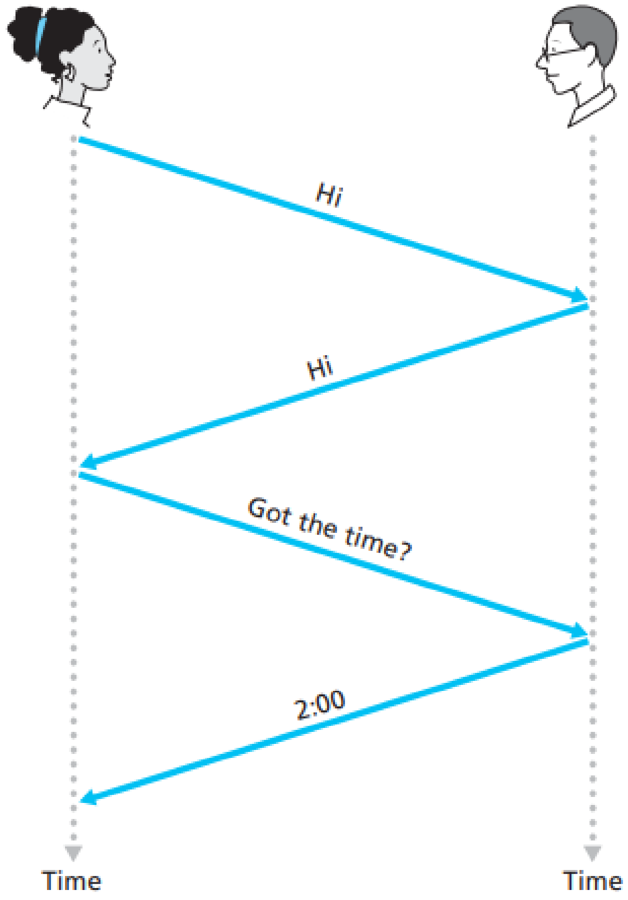
The dual ring topology allows data to be sent in both directions.

Protocol Hierarchies

✓In computer communication **protocol** defines the rules that both the sender and receiver and all inter connected devices need to follow to be able to communicate effectively.

✓A protocol is an agreement between the communicating parties on how communication is to proceed.

✓It is probably easiest to understand the notion of a computer network protocol by first considering some human analogies, since we humans execute protocols all of the time like Figure below.



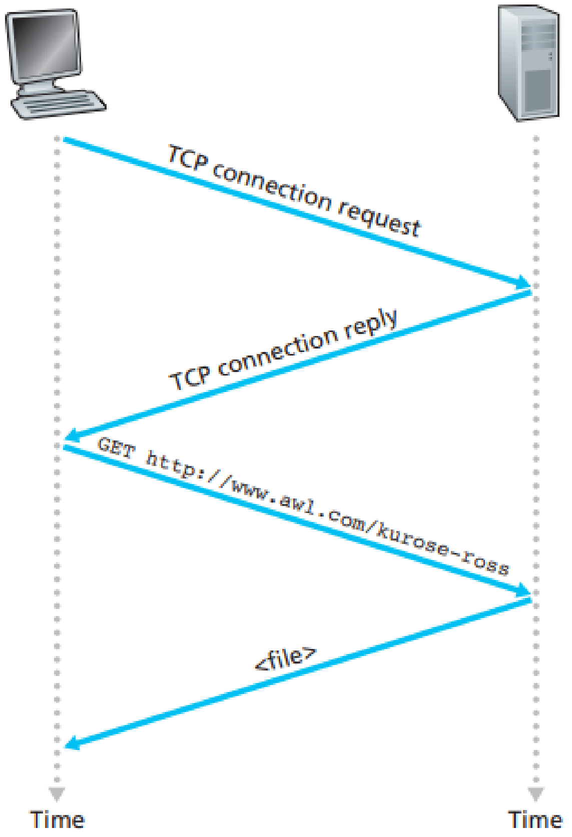
A human protocol

- When you make a request to a **Web server**, then you type the URL (Uniform Resource Locator) of a Web page into your Web browser.

- First, your computer will send a connection request message to the Web server and wait for a reply. The Web server will eventually receive your connection request message and return a connection reply message.

- Knowing that it is now OK to request the Web document, your computer then sends the name of the Web page it wants to fetch from that Web server in a GET message.

- Finally, the Web server returns the Web page (file) to your computer.



A computer network protocol

✓When communication is simple we need only one simple protocol but when communication is complex we need to divide the entire tasks among different layers, where we need a protocol at each layer or protocol layering or protocol stack.

✓To reduce design complexity, most networks are organized as a stack of layers or levels. For example, each of the seven layers of the OSI model hides the implementation details of the lower layers from the upper layers.

✓In a sense each layer is a kind of **virtual machine** offering certain services to layer above or below it.

Example-1

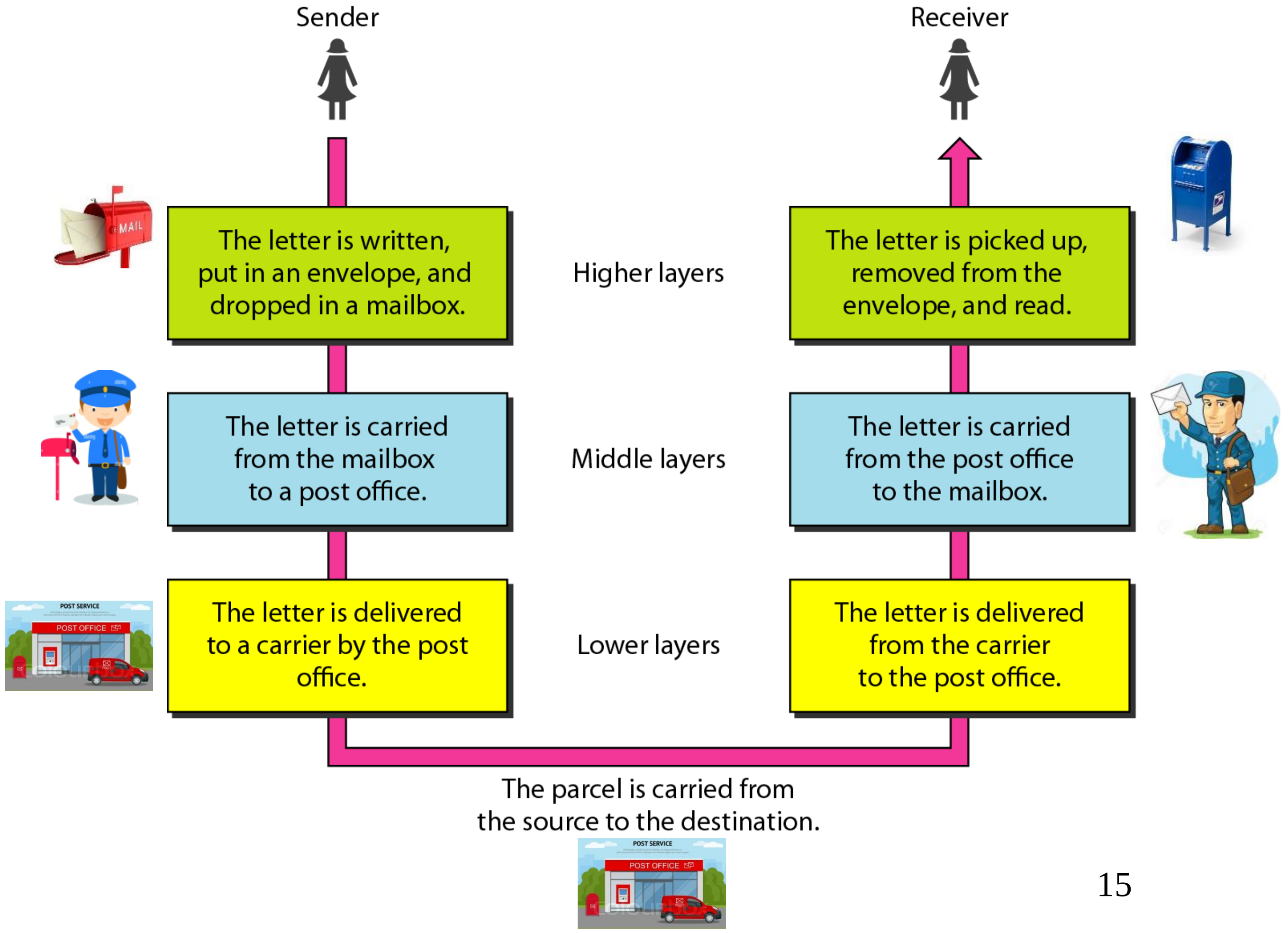
We use the concept of layers in our daily life. As an example, let us consider two friends who communicate through postal mail. The process of sending a letter to a friend would be complex if there were no services available from the post office.

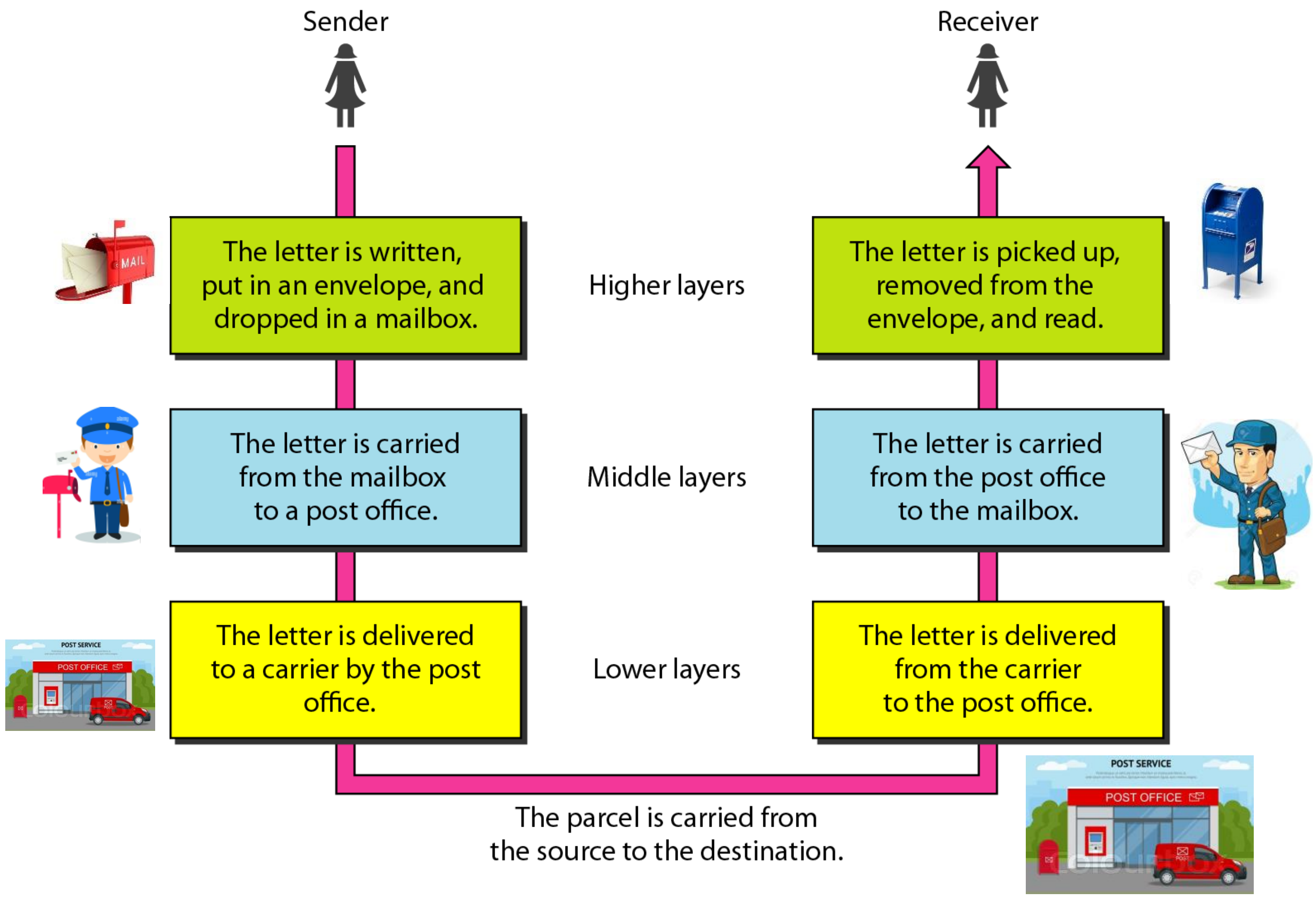
Sender Side

Higher layer: The sender writes the letter, inserts in an envelope, writes the sender and receiver addresses, and drops in a mailbox.

Middle layer: The letter is picked up by a letter carrier and delivered to the post office.

Lower layer: The letter is sorted at the post office and deliver to the carrier transports.





Receiving Side

Lower layer: The carrier transports the letter to the post office.

Middle layer: The letter is sorted and delivered to the recipient's mailbox.

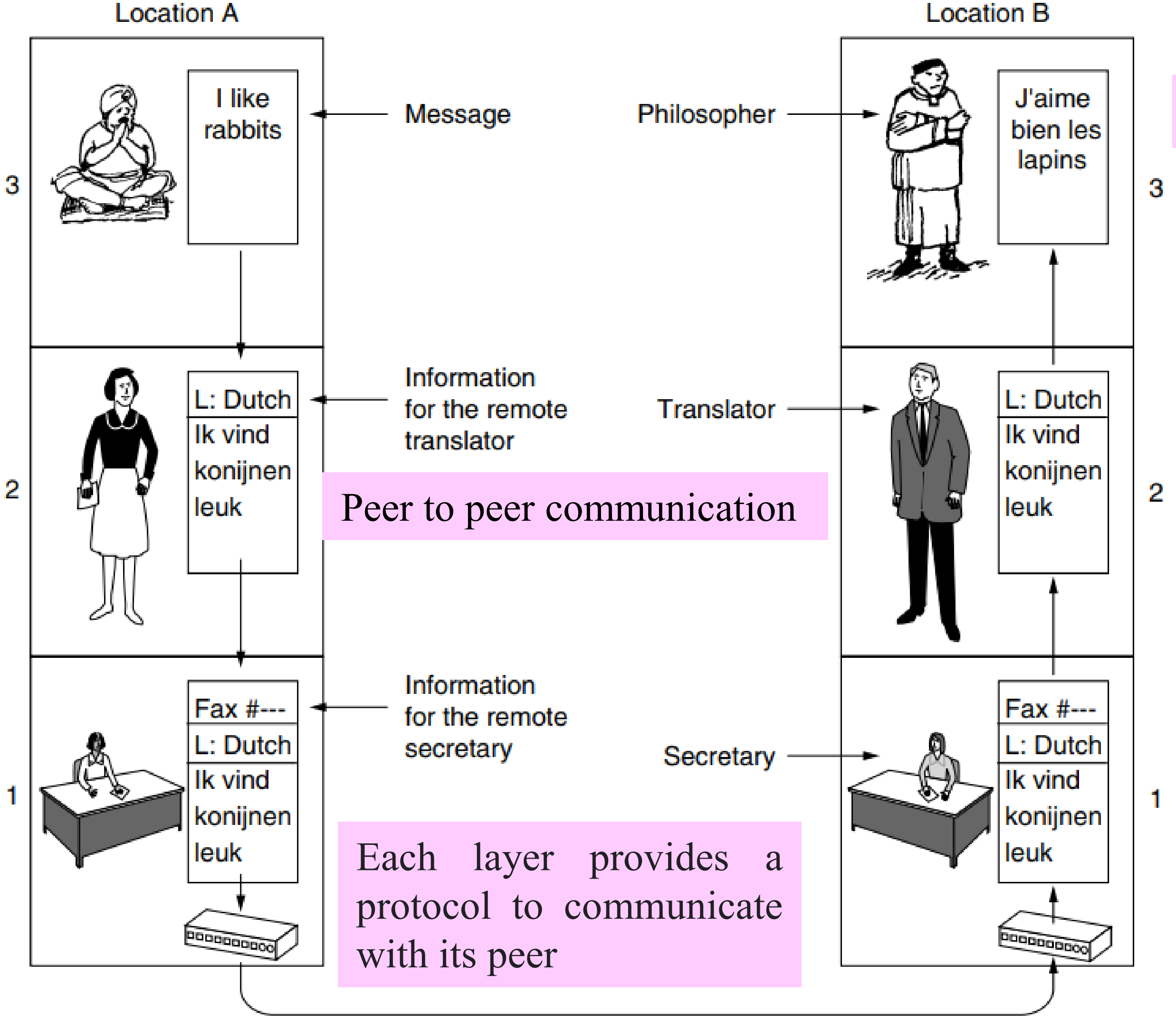
Higher layer: The receiver picks up the letter, opens the envelope, and reads it

Fig.1 Tasks involved in sending a letter

Example-2

An analogy may help explain the idea of multilayer communication.

Urdu and **English**



Chinese and **French**

Peer to peer communication

Each layer provides a protocol to communicate with its peer

Fig.2 The philosopher-translator-secretary architecture

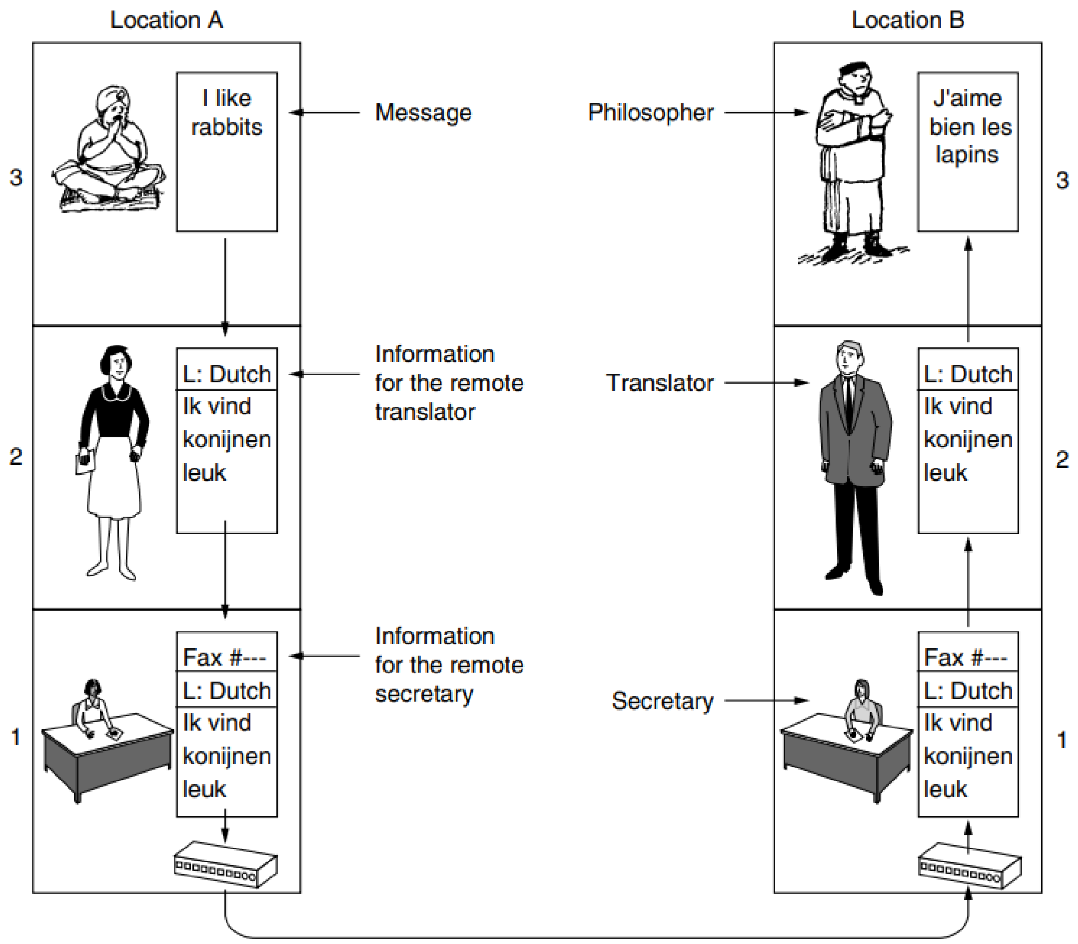
✓Imagine two philosophers (peer processes in layer 3), one of whom speaks Urdu and English and one of whom speaks Chinese and French.

✓Since they have no common language, they each engage a translator (peer processes at layer 2), each of whom in turn contacts a secretary (peer processes in layer 1).

✓Philosopher -1 passes a message (in English) across the 2/3 interface to his translator, saying "I like rabbits," as illustrated in the Fig.

Urdu and English

Chinese and French



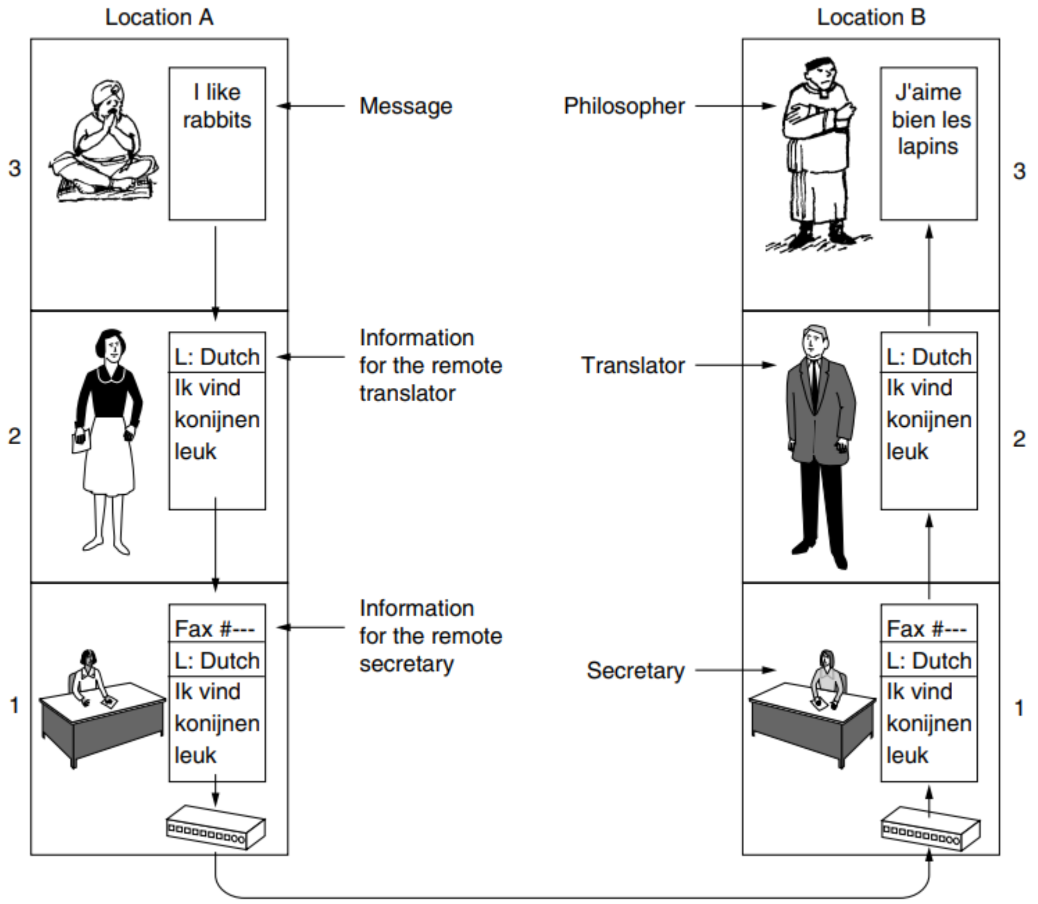
✓The translators have agreed on a neutral language known to both of them, Dutch, so the message is converted to "Ik vind konijnen leuk". The choice of language is the layer 2 protocol and is up to the layer 2 peer processes.

✓The translator then gives the message to a secretary for transmission, by, for example, fax (the layer 1 protocol).

✓When the message arrives, it is delivered to the translator at layer 2. The translator then translate it into French and passed across the 2/3 interface to philosopher 2.

Urdu and English

Chinese and French

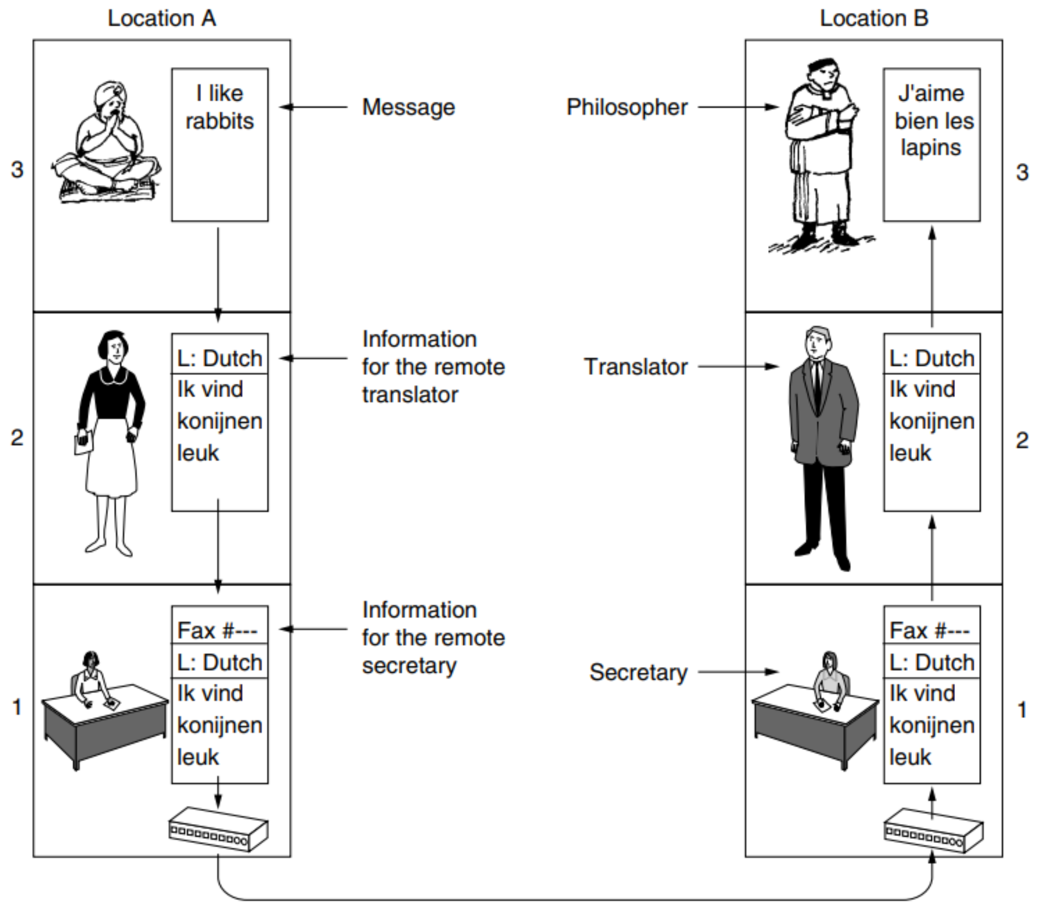


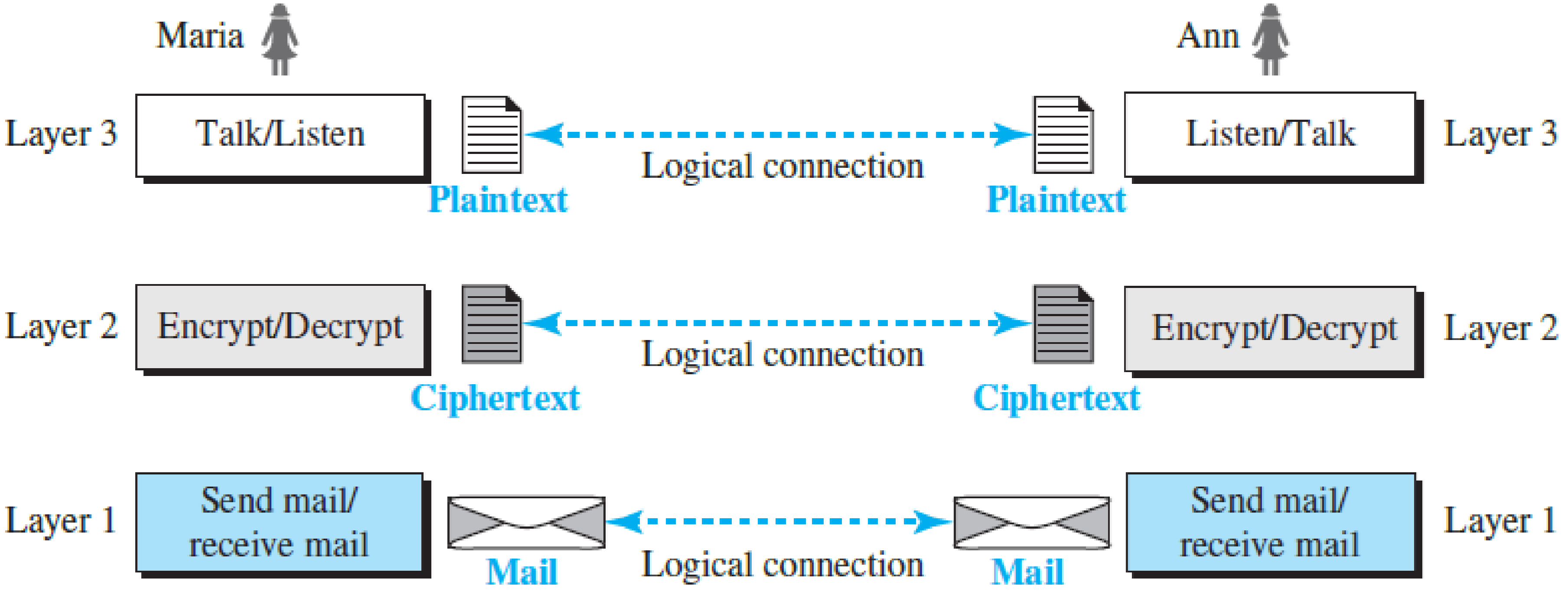
✓Note that each protocol is completely independent of the other ones as long as the interfaces are not changed. The translators can switch from Dutch to say, Finnish, at will, provided that they both agree, and neither changes his interface with either layer 1 or layer 3.

✓Similarly, the secretaries can switch from fax to e-mail or telephone without disturbing (or even informing) the other layers. Each process may add some information intended only for its peer. This information is not passed upward to the layer above.

Urdu and English

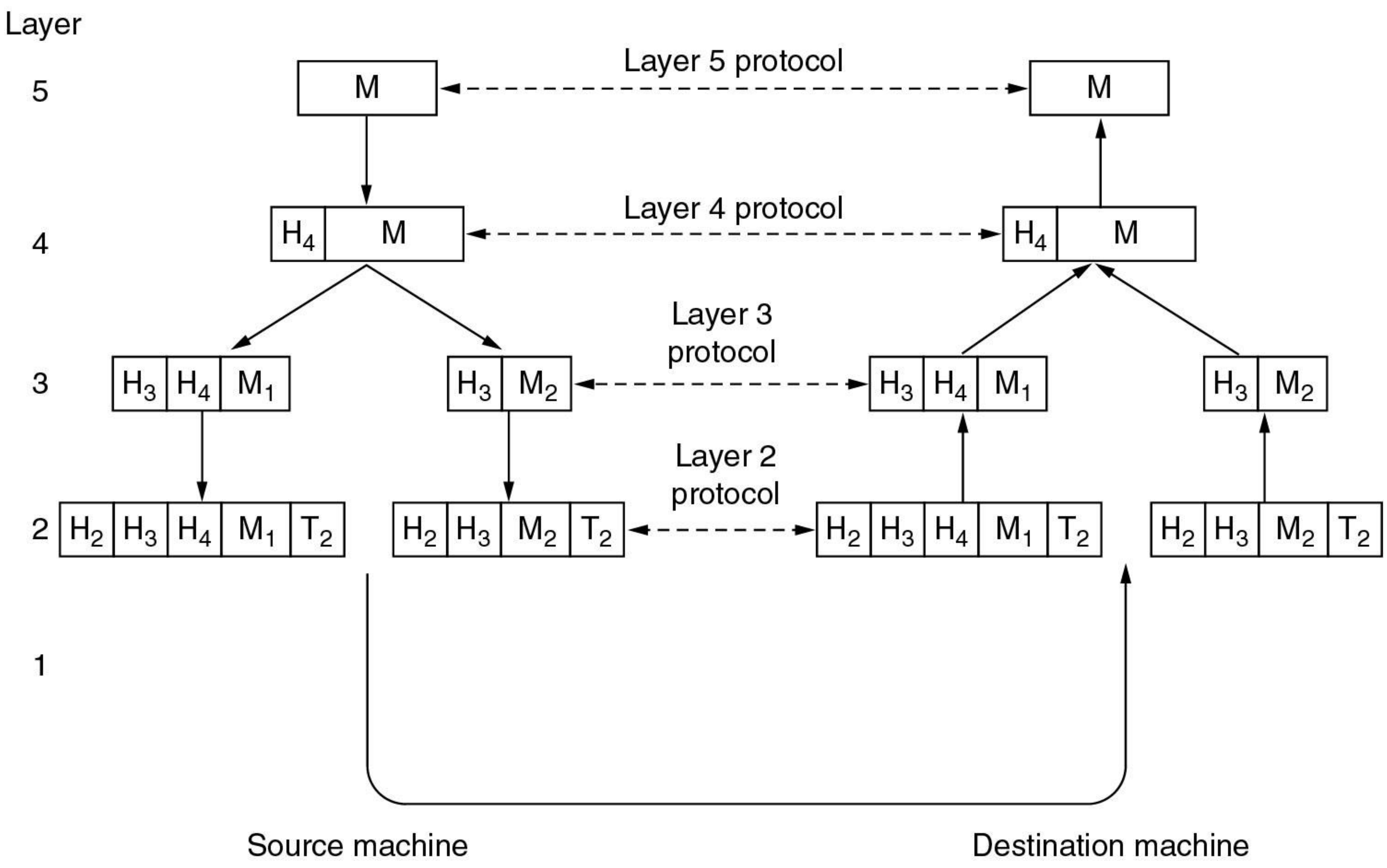
Chinese and French





Layer-to-layer virtual communication is considered as logical connections between each layer as shown in Figure above.

Example information flow supporting virtual communication in layer 5



Layers of networks deals with:

❖Formation of pulse of raw data and modulation

❖Multiplexing/De-multiplexing

❖Addressing

❖Error control

❖Flow control

❖Routing

❖Data encoding for compression

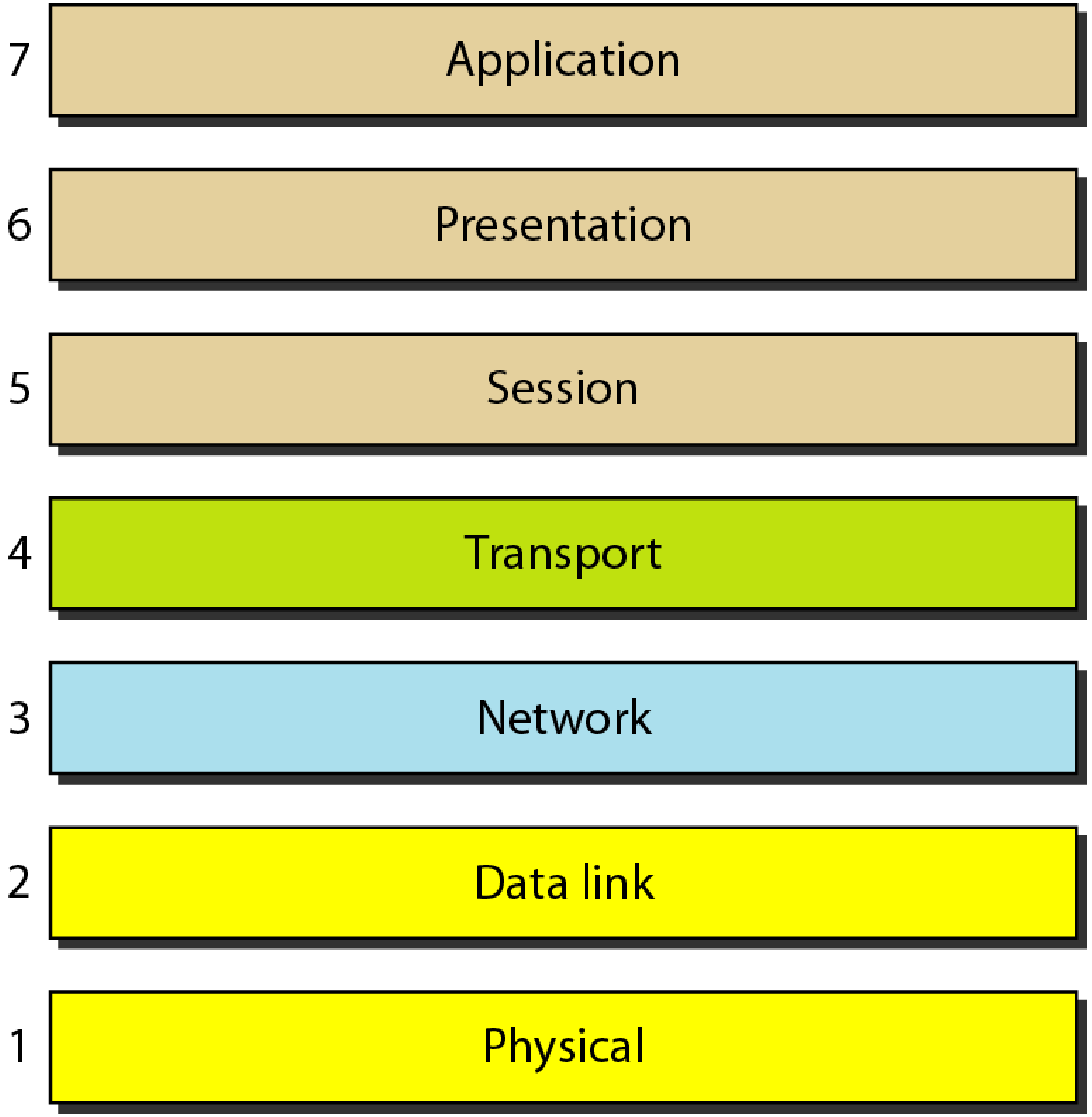
❖Data encryption etc.

The OSI Reference Model

This model is based on a proposal developed by the international standard organization (ISO) as a first step toward international standardization of the protocols used in the various layers (1983).

It was revised in 1995 and the model become OSI (Open System interconnection) **Reference Model** because it deals with connecting open systems-that, systems that are open for communication with other systems.

Seven layers of the OSI model



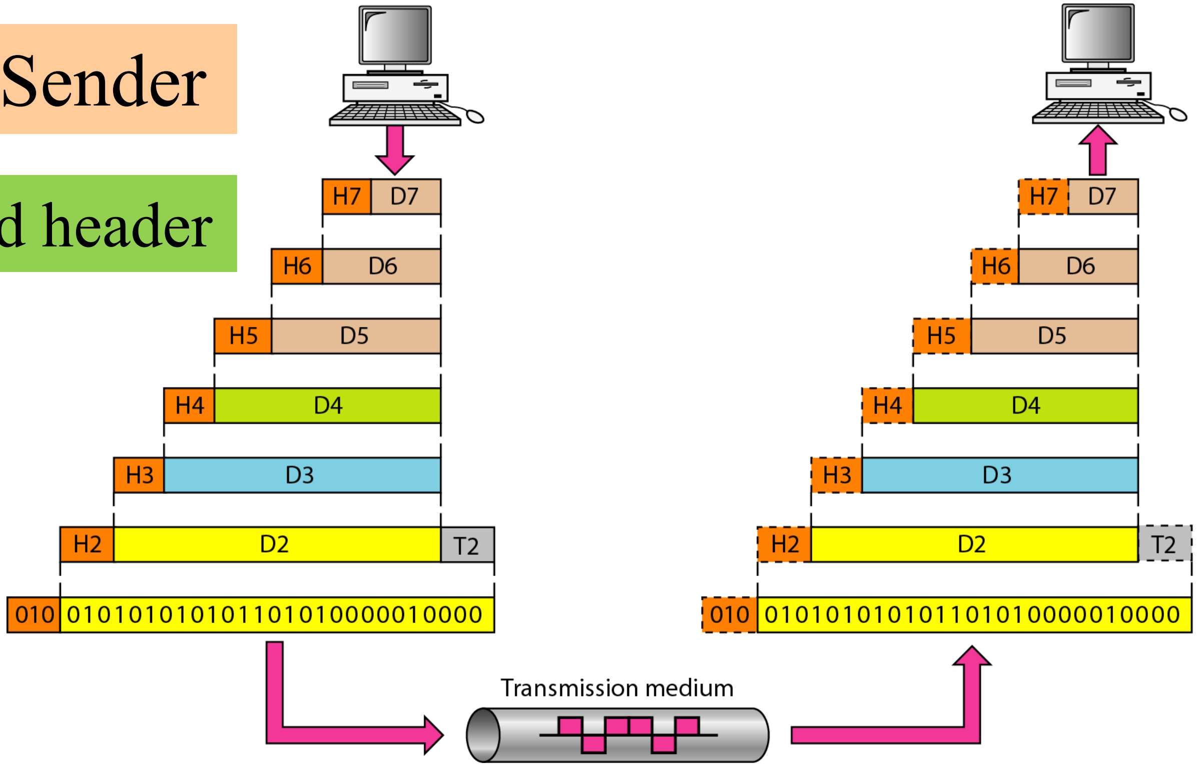
An exchange using the OSI model

Sender

Receiver

Add header

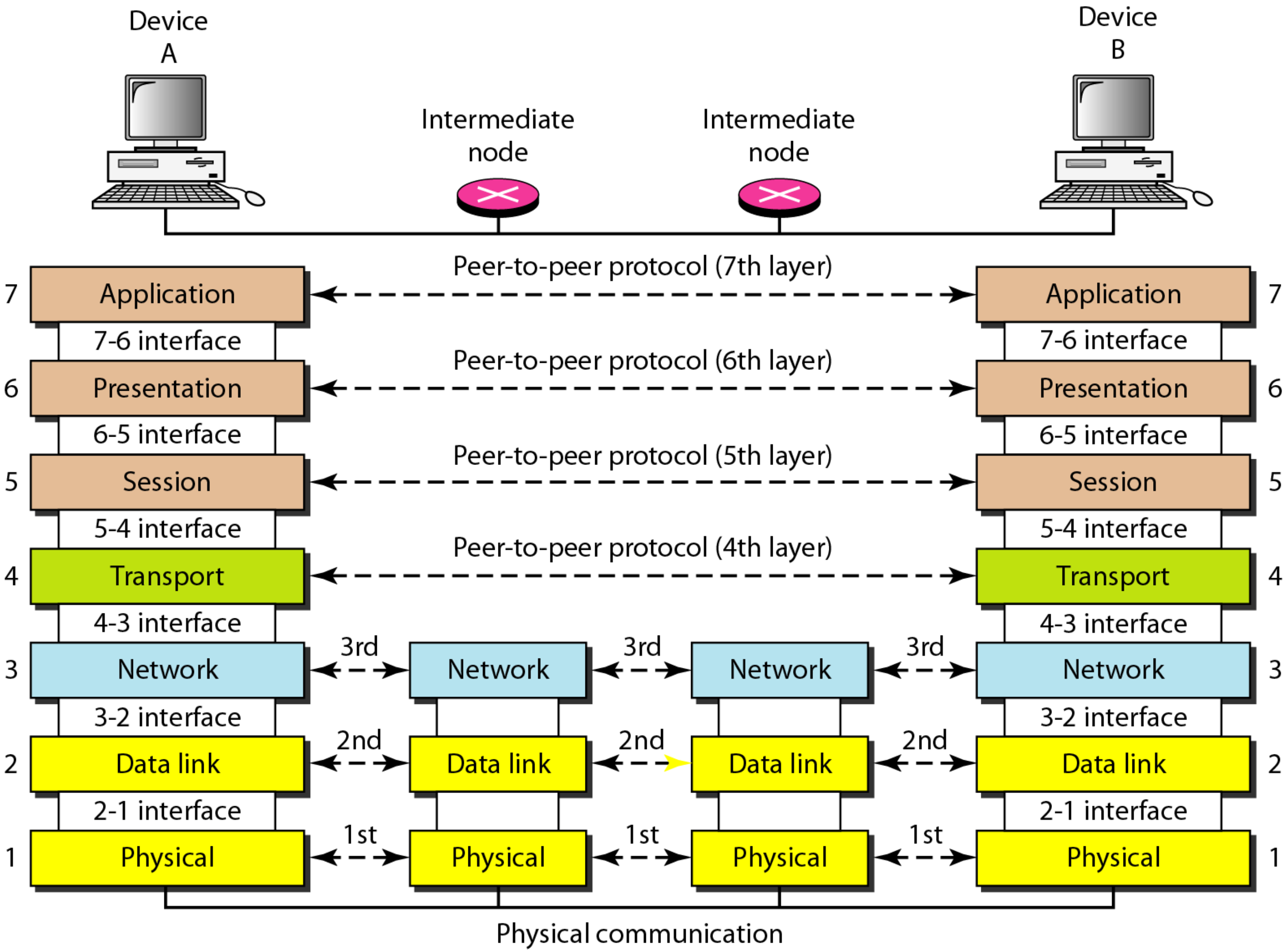
Remove header



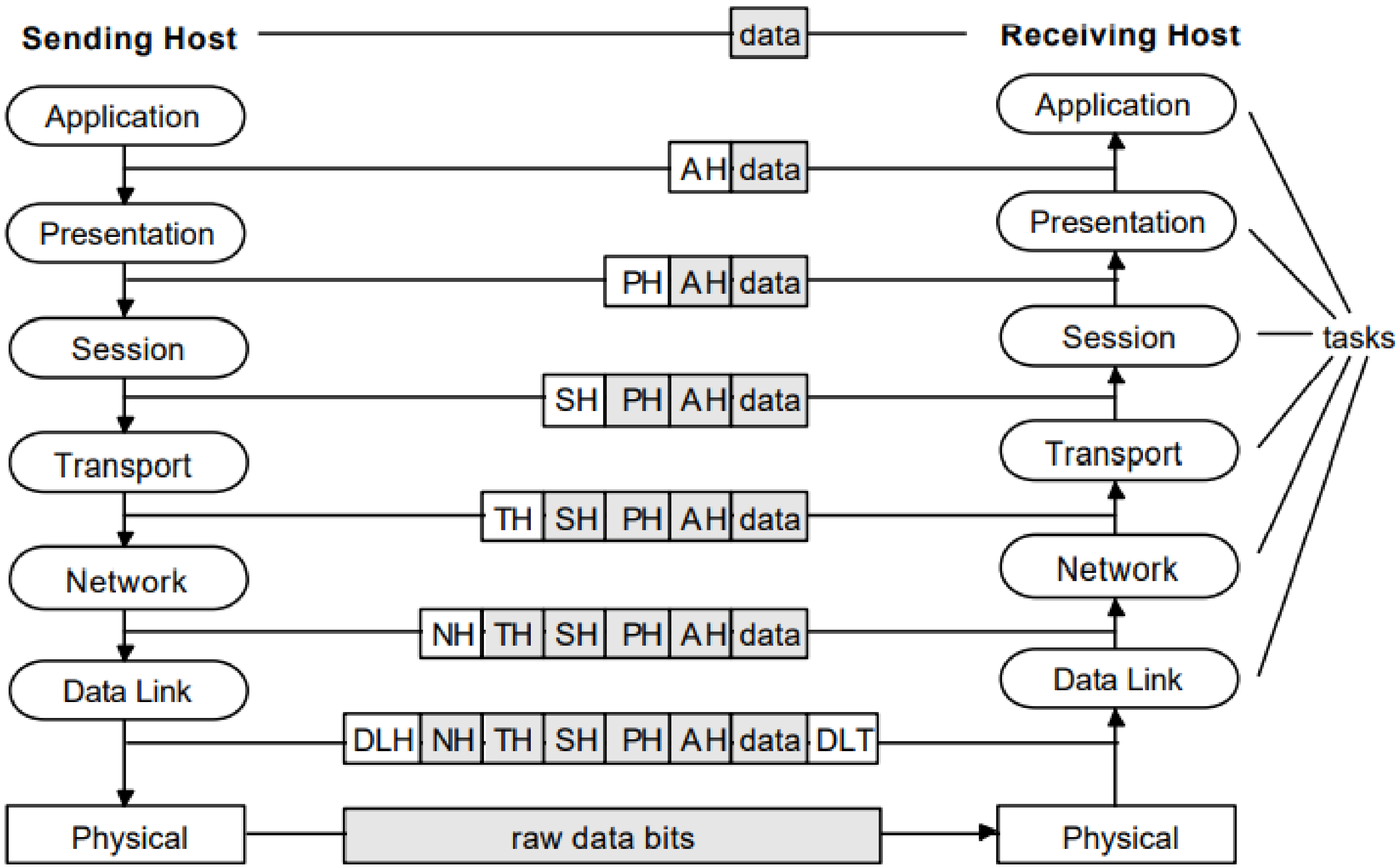
Actual communication occurs at lowest layer with binary pulse and digital modulation.

- ✓ Each layer in the sending device adds its own information to the message it receives from the layer just above it and passes the whole package to the layer just below it.
- ✓ At the receiving machine, the message is unwrapped layer by layer. For example, layer 2 removes the data meant for it, then passes the rest to layer 3. Layer 3 then removes the data meant for it and passes the rest to layer 4, and so on

The interaction between layers in the OSI model



- ✓ Although actual communication takes place only at the physical layer, it is often useful to think of virtual communication between corresponding layers.
- ✓ For example, we can use an imaginary line of communication between the presentation layer on host A and the same layer on host B. This would be characterized by the presentation protocol



Each layer at **transmitting end** performs a tasks by adding an additional piece of information to the message (called header) and the same layer removes the additional piece of information on the **receiving end**.

Physical Layer

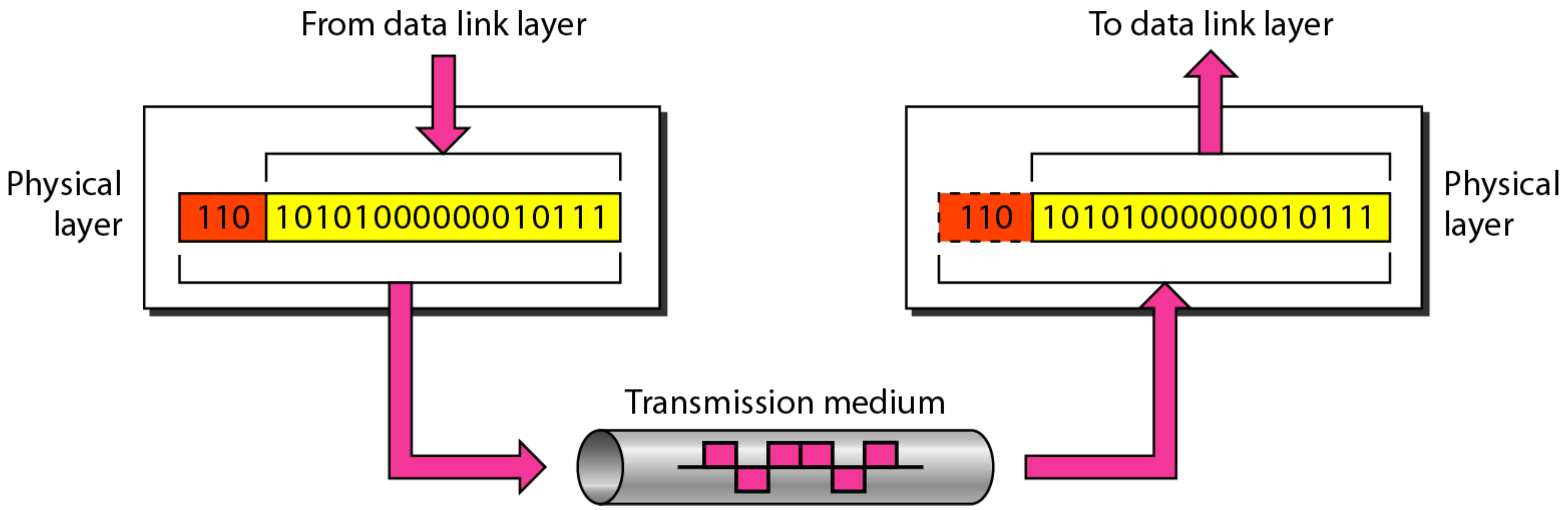
❖The physical layer is concerned with the transmission of raw data bits over communication lines.

❖The physical form (e.g., voltages, frequencies, timing) in which data bits (binary values 0 and 1) are represented. Actually it deals with shape of raw digital pulse i.e. types of **line coding**.

❖The type of modulation (ASK, FSK, PSK, QPSK, 16-QAM etc.) to be used for transmitting digital data over analog transmission lines.

❖Interface to a transmission medium for example connector (RJ45, BNC), MODEM/OLTE but not the physical transmission medium.

Physical layer



- ✓ The physical layer also defines the direction of transmission between two devices: simplex, half-duplex, or full-duplex.
- ✓ In simplex mode, only one device can send; the other can only receive. The simplex mode is a one-way communication. In the half-duplex mode, two devices can send and receive, but not at the same time. In a full-duplex (or simply duplex) mode, two devices can send and receive at the same time.

Data link layer

Data link layer is divided into two sublayer: Logical Link Control (LLC) and Medium Access Control (MAC)

Basic functions of LLC

✓In data link layer the sender breakup the input data into frames (typically few hundred or few thousand bytes) and transmits the frame sequentially.

✓Frames are constructed from data string by adding special bit patterns to the beginning and end of each segment. This allows the receiving end to detect where each frame begins and where it ends.

✓**Error detection:** Some form of error check is included in the frame header. This is constructed by the 'transmitting end' based on the contents of the frame, and checked by the receiving end.

✓When a frame arrives and is corrupted or is lost for any reason in the network, it is retransmitted. The receiver confirms correct receipt of each frame by sending back an acknowledgement frame.

Error correction: In case of multimedia traffic (image, video, voice etc.) the receiver corrects the frame used some complex algorithm like convolutional encoding, Linear block code, R-S code etc.

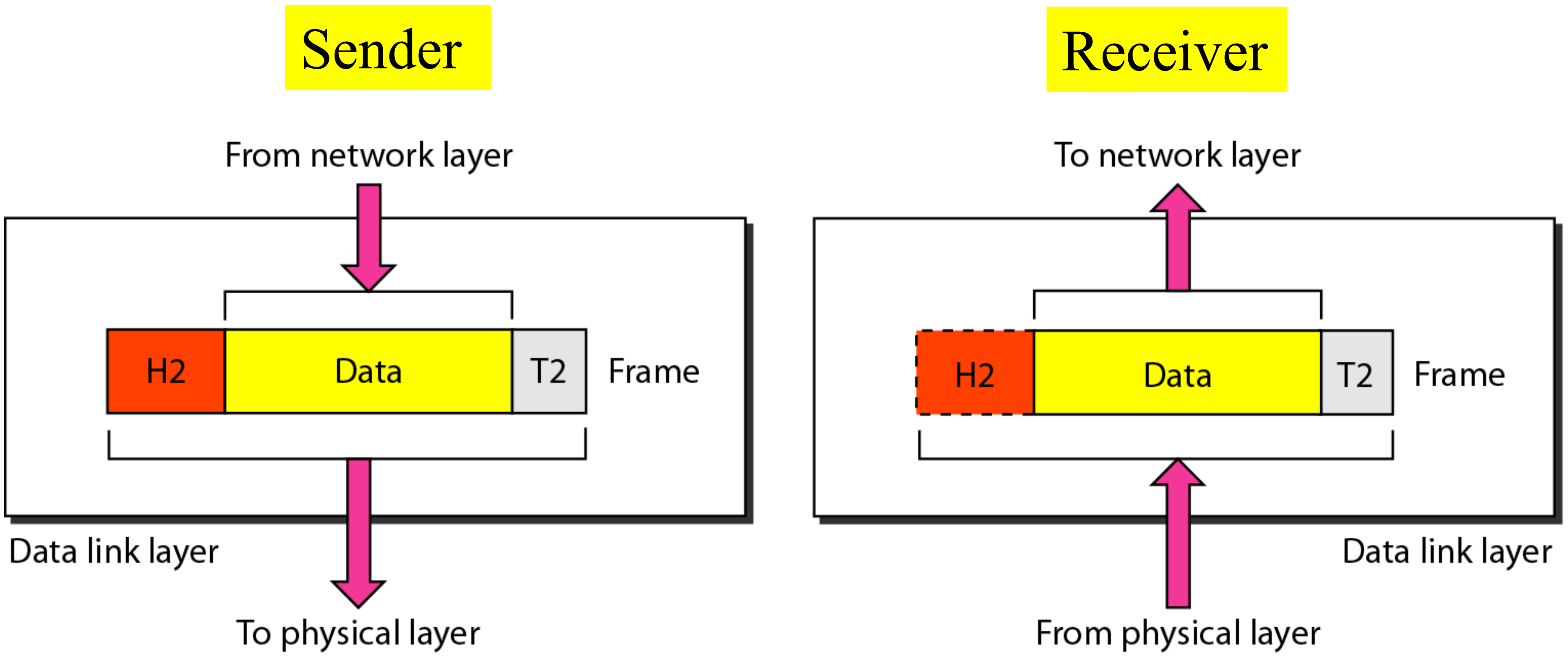
✓**Flow control:** In general, not all communication devices in a network operate at the same speed. Flow control provides a means of avoiding a slow receiver from being swamped by data from a fast transmitter using some buffer.

✓If sender fails to get ack (in case of noise) then the sender sends the same packet, therefore there will be duplication of packet at the receiver. The situation is tackled by this layer.

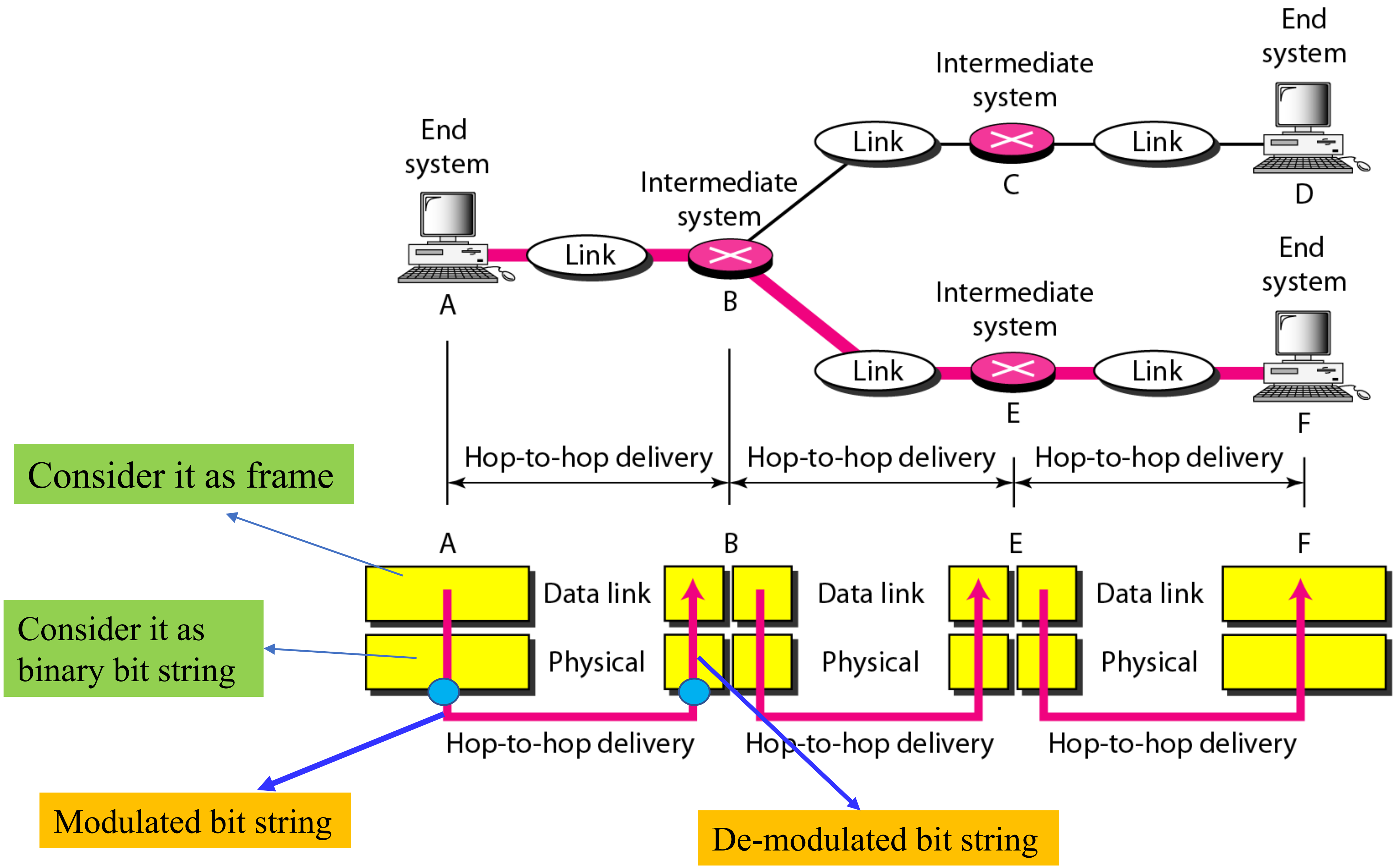
All the above jobs are done by **LLC sub-layer**.

✓Channel sharing among users are done at **MAC sub-layer**.

Data link layer



Hop-to-hop delivery of Data Link Layer



The Network Layer

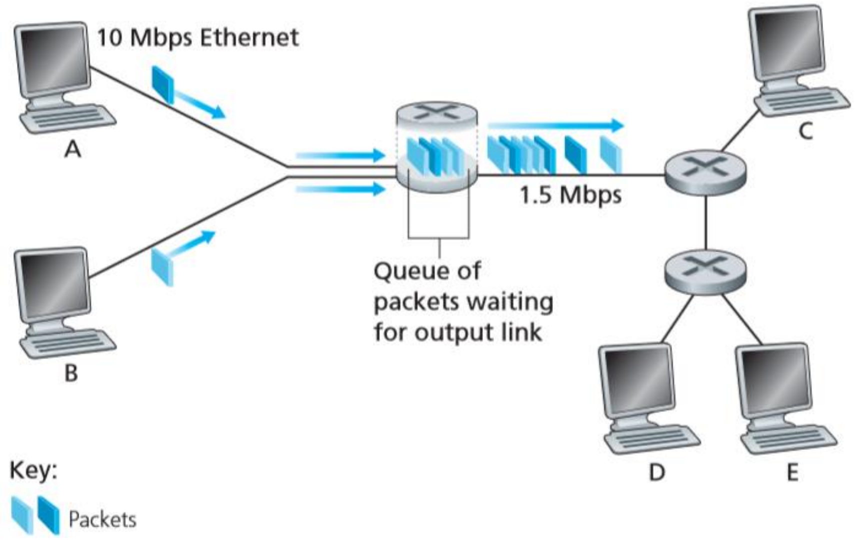
✓At this layer, the unit of data exchanged among nodes is typically called a *packet* rather than a frame, although they are fundamentally the same thing. The *network* layer handles routing of packets among nodes within a **packet-switched network**.

✓Routing of packet is done by routing table of router.

✓Correct ordering of packets to reflect the original order of data.

✓The control of 'traffic congestion' also belongs to the network layer.

✓The quality of service provided (delay, jitter etc.) is also network layer issue. Sum of delays is called latency.

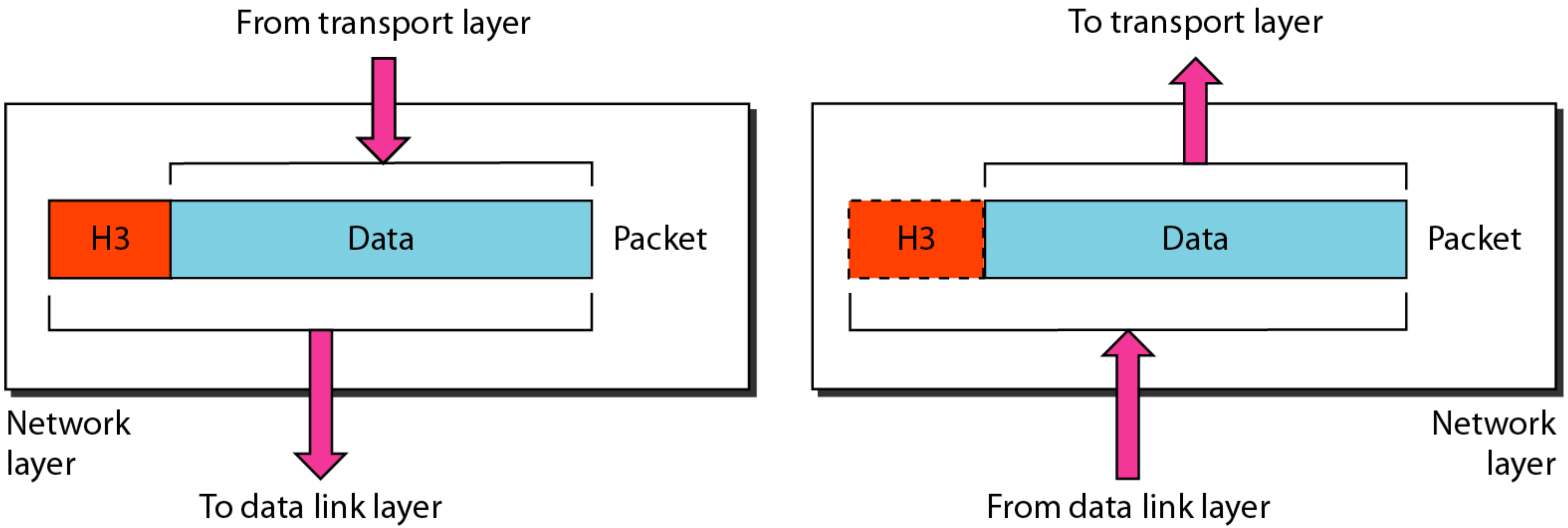


✓The *physical addressing* implemented by the data link layer handles the addressing problem locally. MAC Address ensure that physical address of the computer is unique.

✓If a packet passes the network boundary, we need another addressing system to help distinguish the source and destination systems (area wise addressing). IP Address is a ***logical address*** of the computer and is used to uniquely locate computer connected via a network.

✓The network layer adds a header to the packet coming from the upper layer that, among other things, includes the *logical addresses* of the sender and receiver.

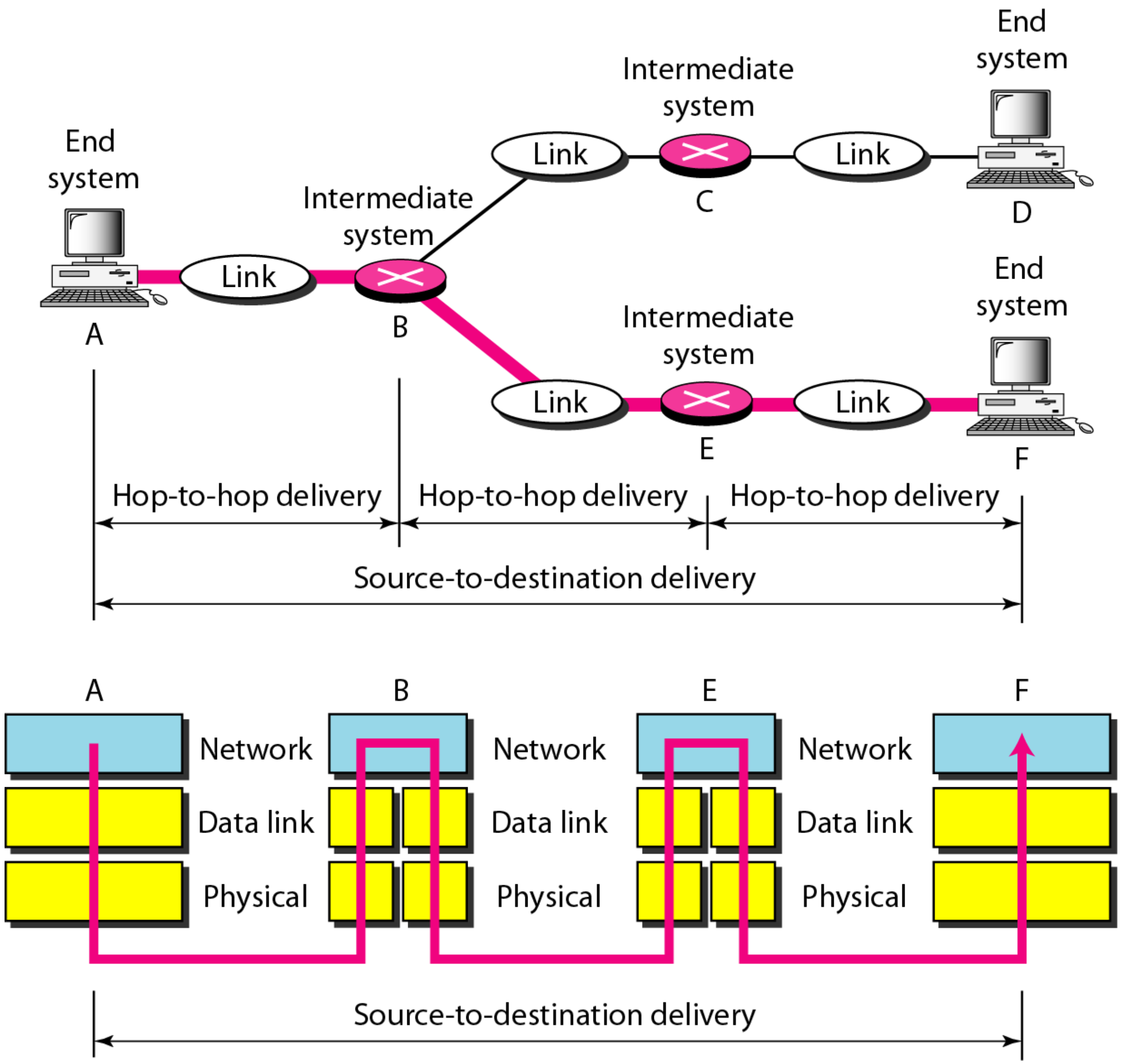
Network layer



✓When a packet has to travel from one network to another to get its destination, many problems can arise. The addressing used by the second network may be different from that used by the first network. The second one may not accept the packet at all because it is too large. The protocol may differ and so on.

✓It is up to the network layer to overcome all these problems to allow heterogeneous networks to be interconnected .

Source-to-destination delivery



The Transport Layer

✓Efficient and cost-effective delivery of data across the network from one host to another. The transport layer and higher layers typically run only on the end hosts and not on the intermediate switches or routers.

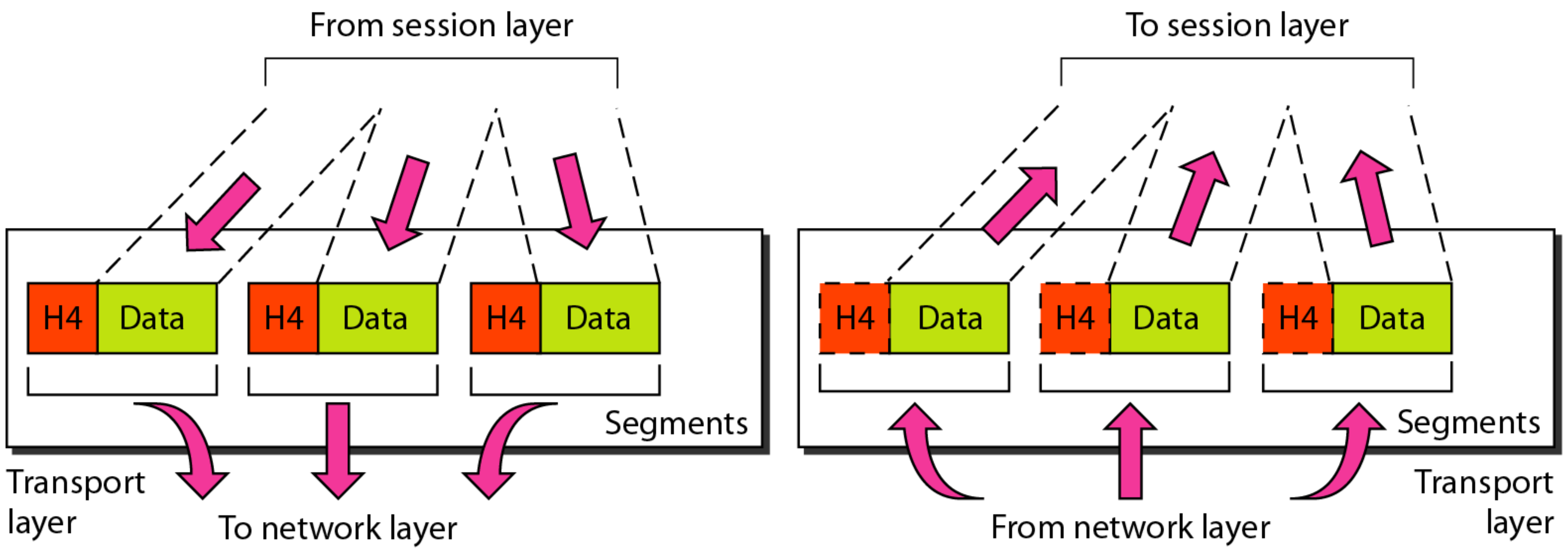
✓Divides the application data into **segments** of appropriately sized for the layers below it.

✓End to end flow control and error control i.e. between hosts.

✓Splitting of data across multiple network connections (parallel TCP links), if necessary, to improve **throughput**, and recombining at the other end.

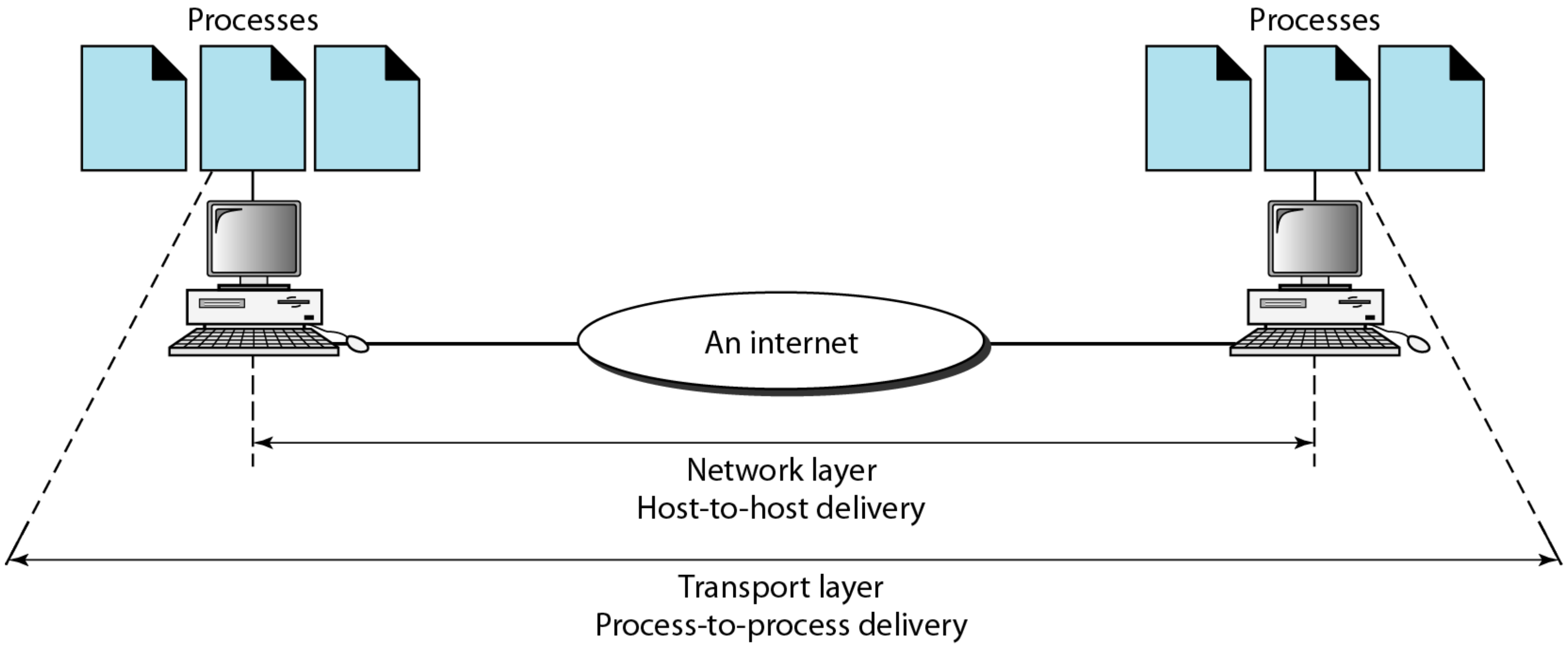
✓TCP and UDP are the example of protocol of this layer

Transport layer



In the Internet there are two transport protocols, TCP and UDP, either of which can transport application-layer messages. TCP provides a connection-oriented service to its applications. The UDP protocol provides a connectionless service to its applications.

The transport layer is responsible for the delivery of a message from one process to another



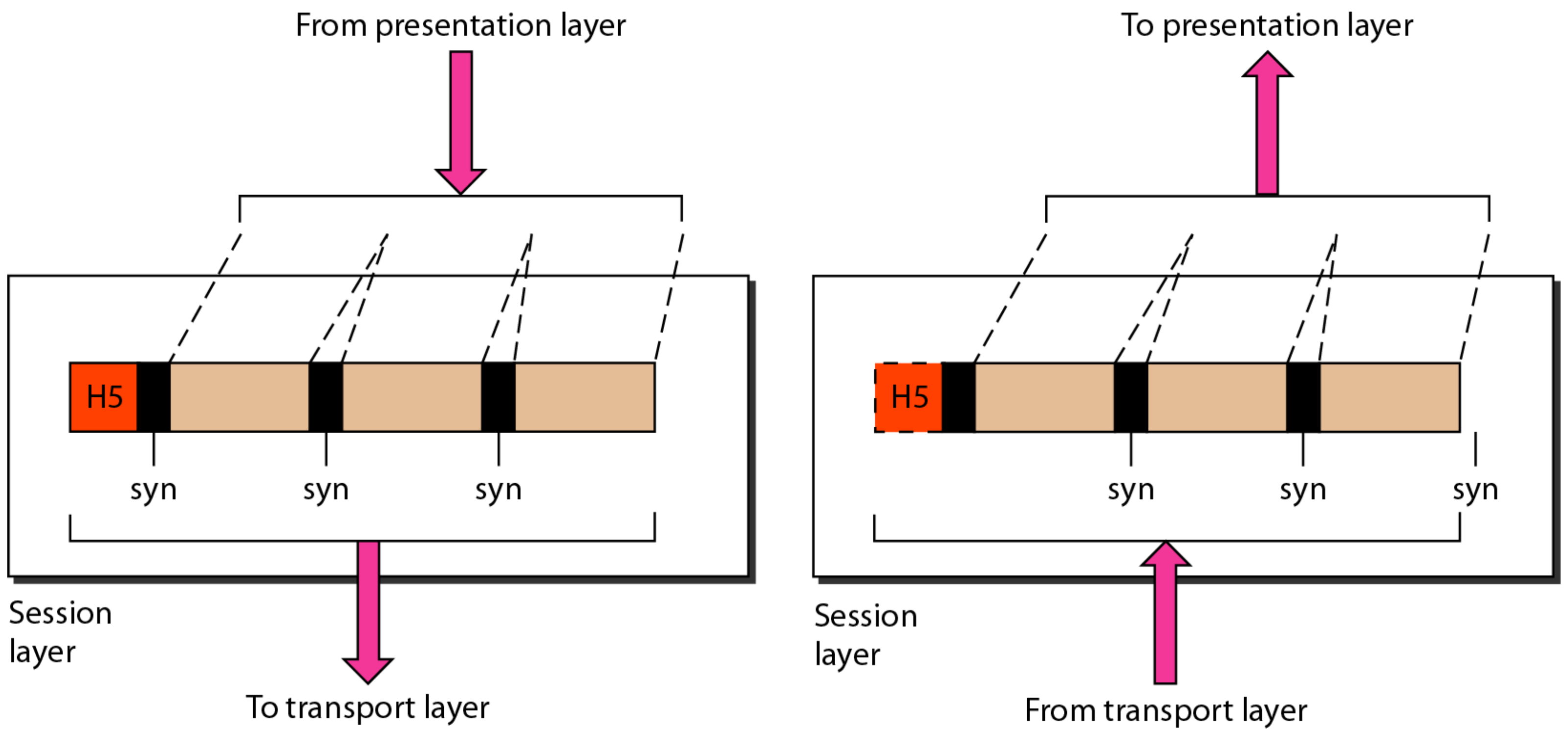
The Session Layer

- It starts, controls and terminates a sessions between the local and remote application (between end-user application processes).

- It allows for full duplex, half duplex or simplex operation, and establishes checkpointing, adjournment, termination, and restart procedures.

- Correct ordering of messages when this function is not performed by the transport layer.

The session layer provides: checkpoints or synchronization points to a stream of data, which is not usually used in the Internet Protocol Suite. During long transmissions sometimes a host becomes disconnected in the midst of communication then checkpointing allow them to continue from where they were crashed.



❖You can use your computer to open a browser window to your favorite Web site, then open a second browser window to the same server and follow different links in each browser. The browser window can act independently because the Web server and your computer have two independent sessions.

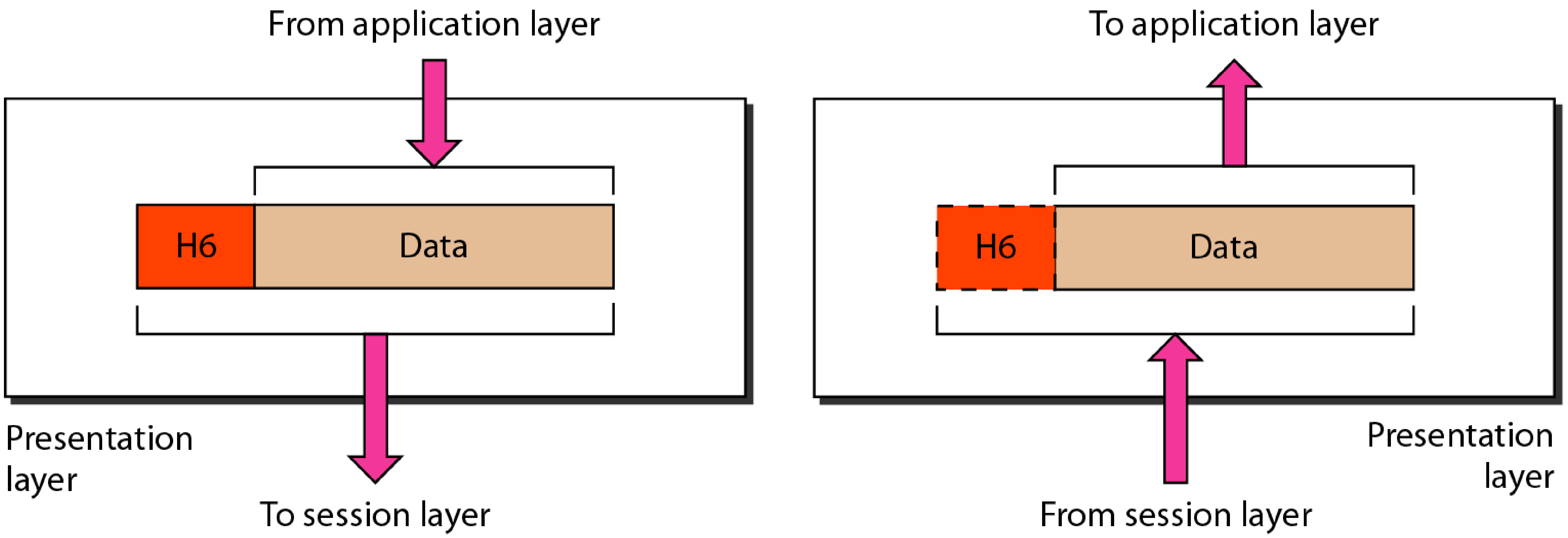
The Presentation Layer

❖The *presentation* layer is concerned with the format of data exchanged between peers, for example, whether an integer is 16, 32, or 64 bits long.

❖More explicitly, this layer is responsible for data translation into a standard format. Examples are ASCII (American Standard Code for Information Interchange, 7-bit character encoding) text, EBCDIC (Extended Binary Coded Decimal Interchange Code, 8-bit character encoding), JPEG pictures, MPEG video and MP3 music formats. Conversion between the binary representation of application data and a common format for transmission between peer applications.

❖For example, the Presentation Layer can apply sophisticated compression techniques so fewer bytes of data are required to represent the information when it's sent over the network.

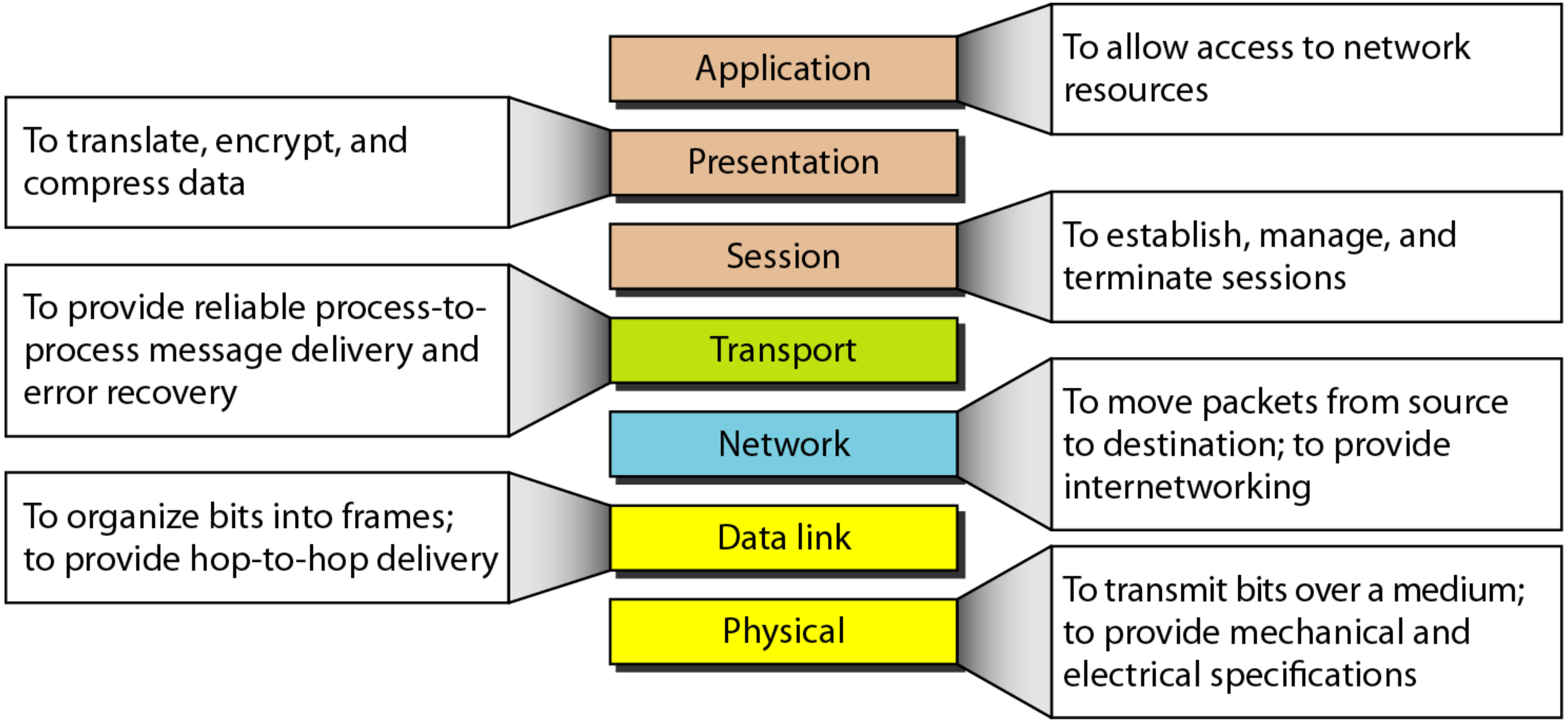
❖This layer is also responsible for encryption and decryption for security purposes, as well as data compression. It is sometimes called the syntax layer.

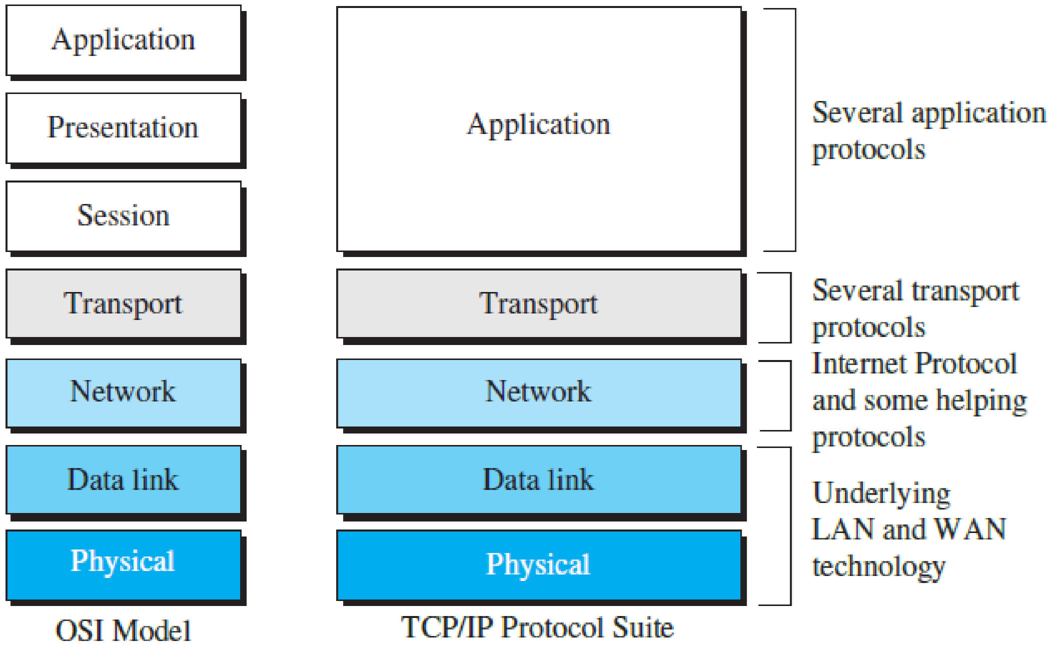


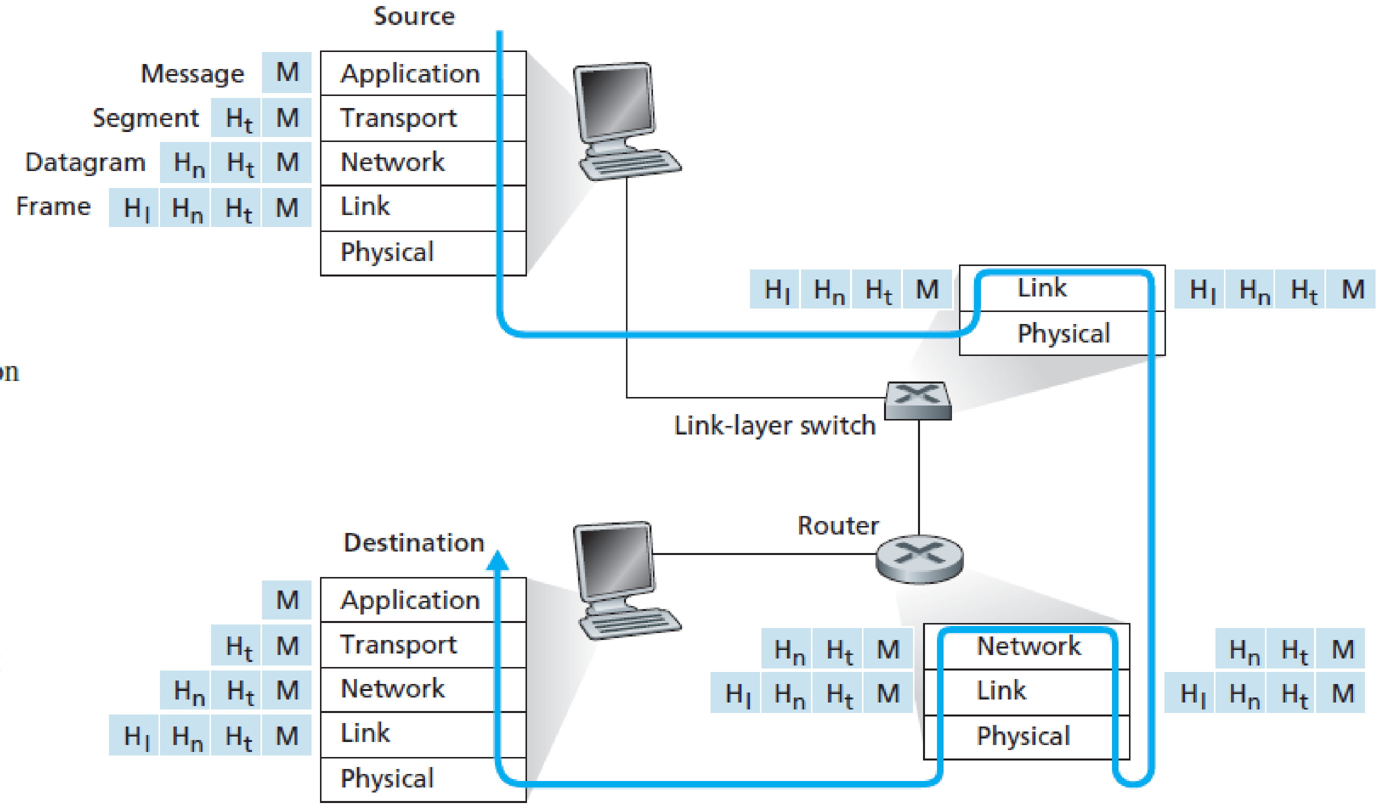
Application layer

- ❖The application layer is where network applications and their application-layer protocols reside. File transfer, web browser, e-mail, DNS service etc. are applications and implemented using some application layer protocols.
- ❖The Internet's application layer includes many protocols, such as the HTTP protocol (which provides for Web document request and transfer), SMTP (which provides for the transfer of e-mail messages), and FTP (which provides for the transfer of files between two end systems). This layer provides a consistent interface to the network for all computer software i.e. provides OSI environment.
- ❖This layer also provides security like cryptography, Digital signature, Firewall etc.

Summary of layers







Hosts, routers, and link-layer switches; each contains a different set of layers, reflecting their differences in functionality.

Signal and Switching of Computer Network

Baseband and Passband Signal

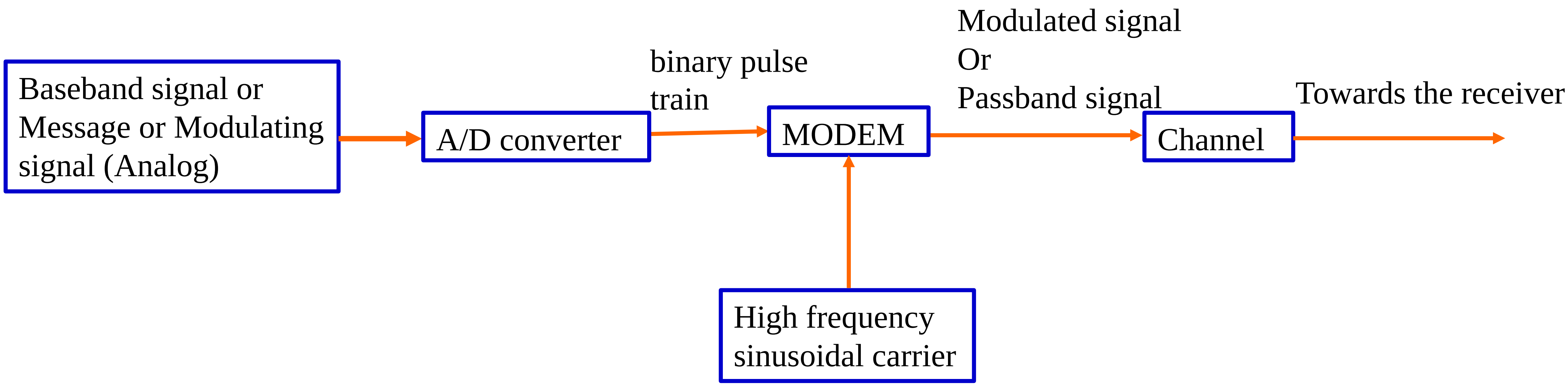
✓The objective of digital modulation is to convert the rectangular digital pulses (called digital baseband signal) to smooth sinusoidal wave (called passband signal) hence considerable reduction in bandwidth is achieved.

✓The bandwidth reduction is essential to cope the transmitted wave with the transmission medium (channel) of lower capacity bandwidth. This baseband to passband conversion or its reverse operation is under physical layer.

Baseband signal or Message or Modulating signal (binary pulse train) → High frequency sinusoidal carrier → Modulated signal Or Passband signal

Baseband (pules) → Passband (sinusoidal waves)

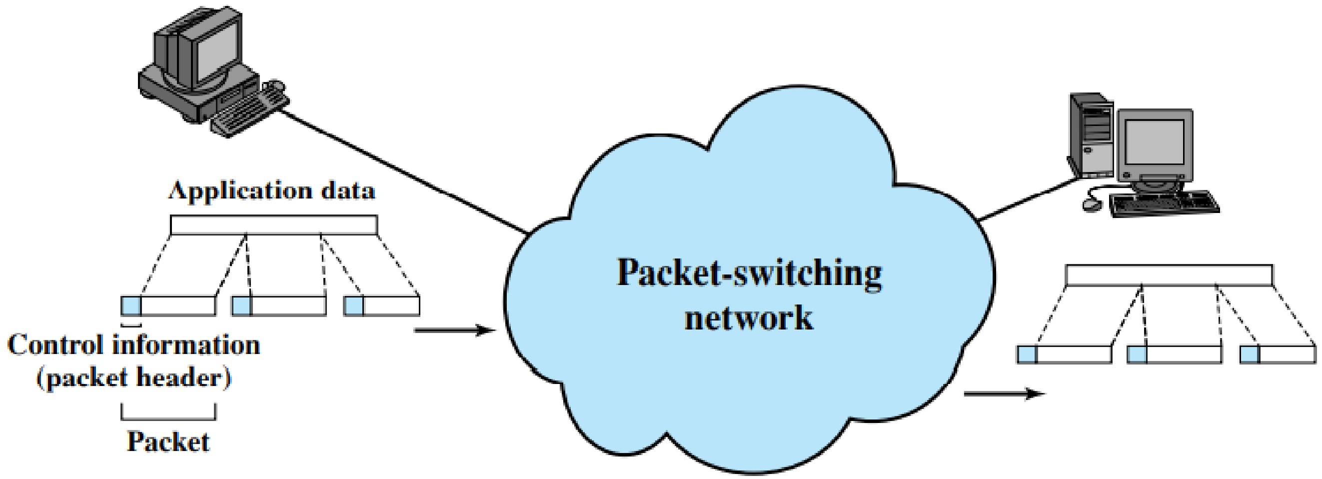
For example **MODEM** is connected between PC and Internet cable to convert the rectangular data pulse from the computer (infinite bandwidth) into continuous wave (called **modulation** during transmission, for example FSK) of lower bandwidth to cope with the allowed bandwidth of the Internet line (transmission medium). During reception (for example downloading of data) the modulated wave is converted to digital pulse train called **de-modulation**.



Circuit and Packet Switching

- ✓ In **circuit switch**, a switchport or contact (for example, connecting two parties of telephone call) is made on from call setup to call termination. The switchport is dedicated to a particular telephone call and the message either in analog or digital (for example TDMA of GSM or E1 link of TDM) form is passed through the switch port.

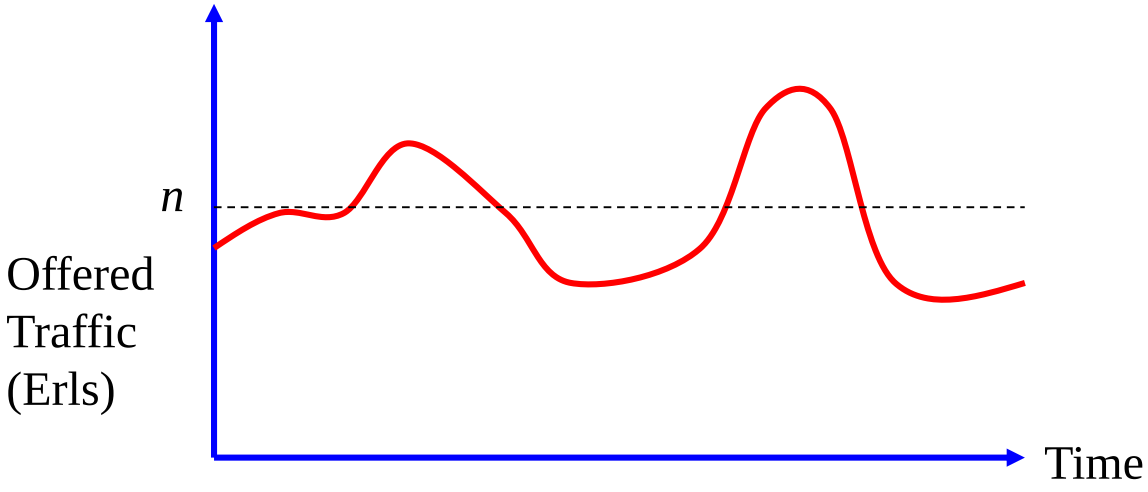
- ✓ In **packet switching** the information/message regardless of size is converted into suitably-sized blocks, called *packets*. Each packet contains a portion (or all for a short message) of the user's data plus some control information.



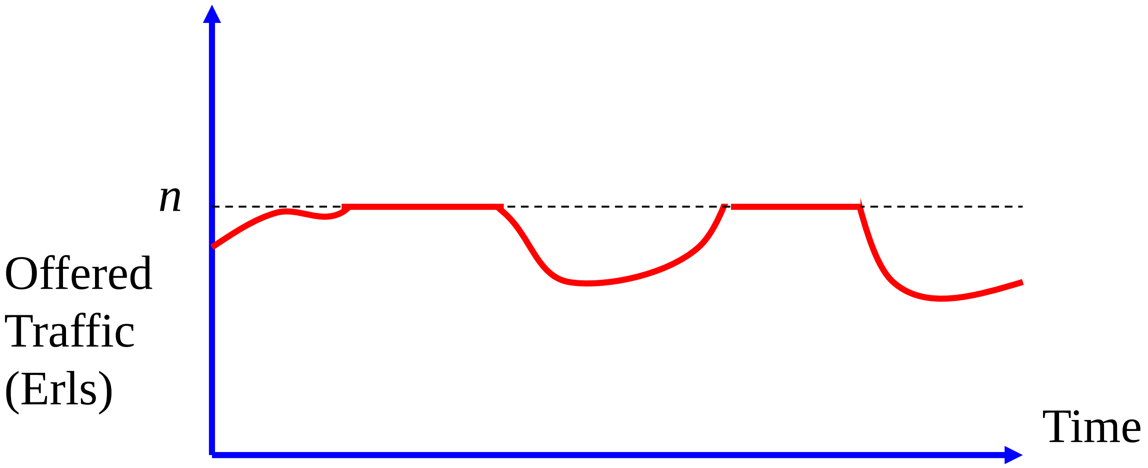
- ✓ In circuit switching (for example TDMA of GSM or E1 link of TDM) after call setup a time slot is dedicated for a user even when no data is transferred but in packet switching the idle time slot is used by another user which makes optimum use of trunks in packet switching.

- ✓ Packet switching technique enables a trunk to carry 1.0 Erlang during busy the hour because of its storing capability but for the case circuit switch the carried traffic depends on the pattern of offered traffic.

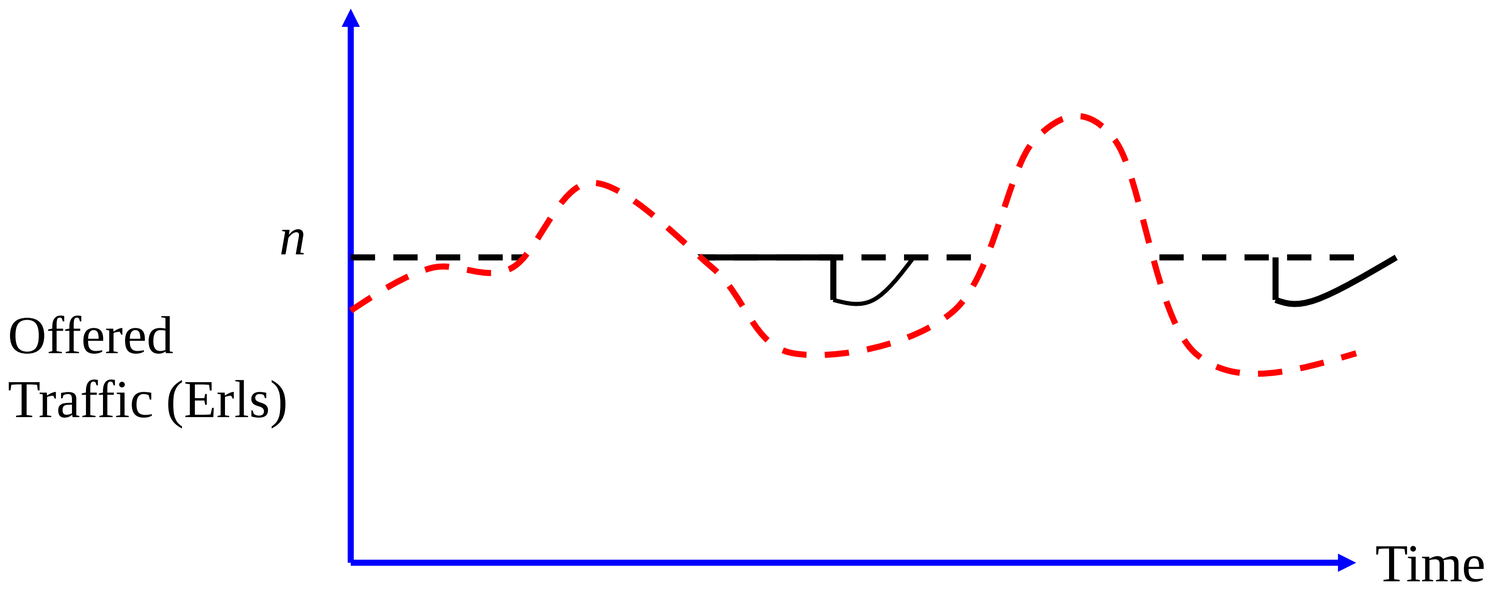
❖For example, if huge traffic arrives with in an observation period [T_1 T_2] which is beyond the capacity of the switch but after some duration offered traffic is lowered to the capacity of the switch. The circuit switch will experience huge loss of traffic but packet switch will carry the entire traffic using its buffer/queue. A comparison of circuit and packet switching system of *n* trunks case is shown in fig. below.



(a) Offered traffic



(b) Carried traffic by circuit switching system (overflow traffic is truncated)



Carried traffic by packet switching system (overflow traffic is carried in another time)

❖Transmission of **real time data** like audio and video which need a constant arrival rate in sequencing order to play the signal instantly at receiving end need **circuit switching** on the other hand packet switching is more efficient for data which can withstand delays (such as e-mail, word file)

Comparison of packet and circuit switching techniques:

- ✓ Line efficiency is greater, because of utilization of idle time in routing queueing packets. In packet switch, the carried traffic = offered traffic i.e. there is no loss of traffic. In circuit switch the carried traffic depends on the pattern of offered traffic

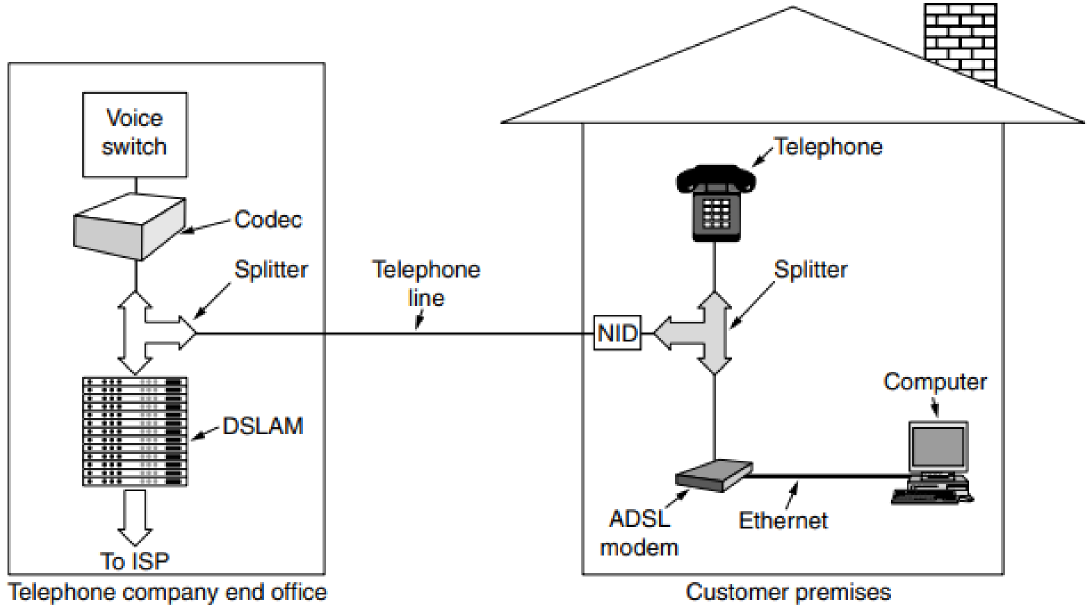
- ✓ A packet-switching network can perform data-rate conversion. Two stations of different data rates can exchange packets because each connects to its node at its proper data rate.

- ✓ When traffic becomes heavy on a circuit-switching network, some calls are blocked; that is, the network refuses to accept additional connection requests until the load on the network decreases. On a packet-switching network, packets are still accepted, but delivery delay increases.

- ✓ Priorities can be used. If a node has a number of packets queued for transmission, it can transmit the higher-priority packets first. These packets will therefore experience less delay than lower-priority packets

ADSL (Asymmetric Digital Subscriber Line)

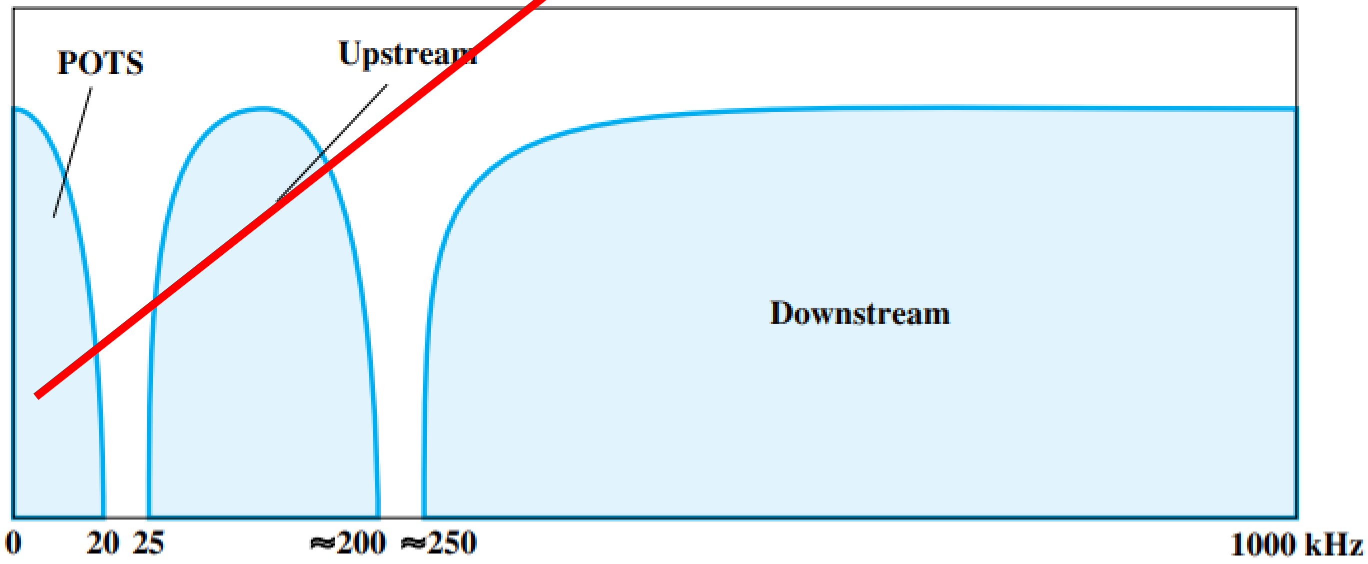
- ✓ ADSL (Asymmetric Digital Subscriber Line), which provides Internet access over normal telephone lines. A typical ADSL arrangement is shown in Fig. below. In this scheme, a telephone company technician must install a NID (Network Interface Device) on the customer's premises. This small plastic box marks the end of the telephone company's property and the start of the customer's property.
- ✓ Close to the NID (or sometimes combined with it) is a splitter, works as a filter bank.
- ✓ DSLAM (Digital Subscriber Line Access Multiplexer), which contains the same kind of digital signal processor as the ADSL modem



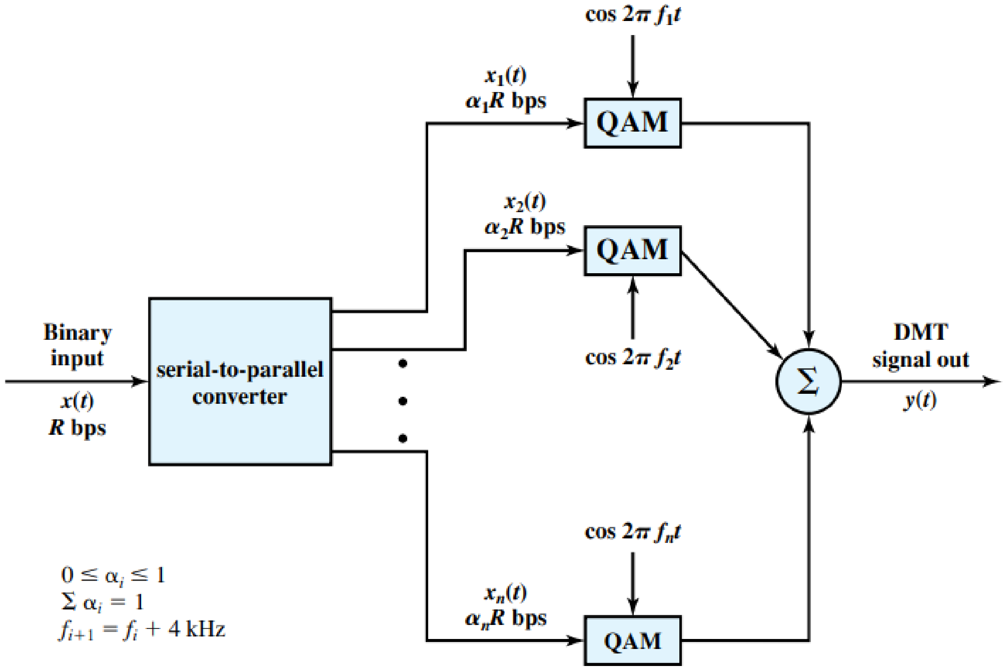
A typical ADSL equipment configuration.

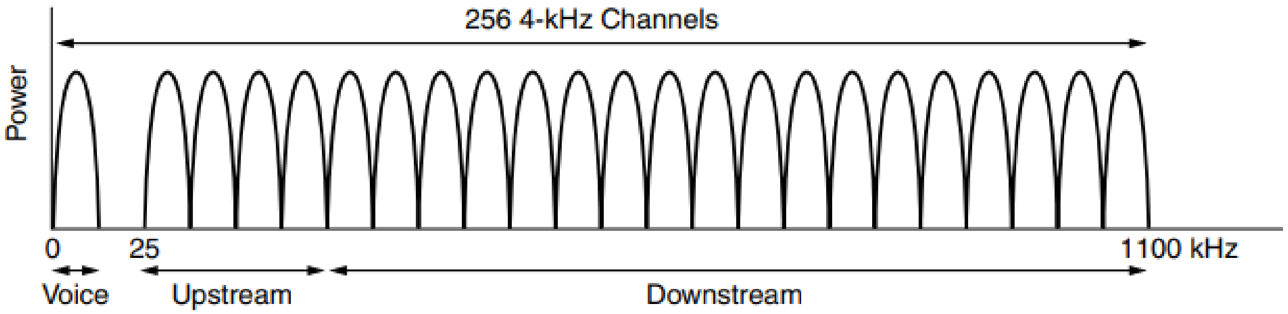
- ✓ ADSL provides a different bandwidth from the subscriber to the telephone company's central office (upstream) than it does from the central office to the subscriber (downstream).
- ✓ The downstream bit rate ranges from 1.5Mbps to 6 Mbps with increment of T1 (1.54 Mbps of 24 voice channels).
- ✓ Upstream is bidirectional channel of rate in the range 64Kbps to 640 kbps with increment of 64kbps.
- ✓ Voice channel of 64kbps for telephone call.

POTS (plain old telephone service).



✓ ADSL uses OFDM or d DMT (Discrete Multi Tone), whose arrangement is shown below. Channel 0 is used for POTS (Plain Old Telephone Service). Channels 1–5 are not used, to keep the voice and data signals from interfering with each other. Of the remaining 250 channels, one is used for upstream control and one is used for downstream control. The rest are available for user data.





The bit stream to be transmitted is divided into a number of sub-streams, one for each subchannel that will carry data. The sum of the data rates of the sub-streams is equal to the total data rate. Each sub-stream is then converted to an analog signal using quadrature amplitude modulation (QAM)